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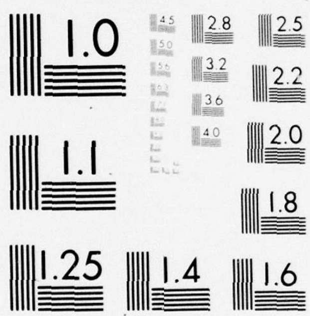
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MODIA: Vol. 4
The Resource Utilization Model

Margaret Gallegos

A Project AIR FORCE report
prepared for the
United States Air Force

Rand
SANTA MONICA, CA. 90406

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A description of the Resource Utilization Model component of MODIA (a Method Of Designing Instructional Alternatives), a system developed to help Air Training Command plan technical courses. The model is a computerized, discrete event simulation of course operations for planning. It simulates resource demand, resource use, and student queuing generated by student progress through the potentially complex flow patterns of a course. Among its many options are variable or fixed rates of student progress and prespecification of resource availability by the planner or determination of resource requirements by the model. It ascertains such items as rates of resource use, average time to graduation, points at which students must wait for resources, and average and peak student loads. Another MODIA component, described in R-1702-AF, helps the planner generate course designs for input to the model. An overview of MODIA is given in R-1700-AF. (Author)

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PREFACE

This report documents research conducted under Project AIR FORCE (formerly Project RAND) by The Rand Corporation. The work described here was performed as part of the project entitled "Analysis of Systems for Air Force Education and Training" under Rand's Manpower, Personnel, and Training Program. It is the fourth in a series presenting Rand's MODIA planning system. MODIA, a *M*ethod of *D*esigning *I*nstructional *A*lternatives, is a system of people, computer programs, and procedures that allows the rapid specification and simulation of courses of instruction during the early stages of instructional design. It augments and can be used in the present Air Force instructional systems development (ISD) process.

The development of MODIA has been supported by the Deputy Chief of Staff/Personnel, Headquarters United States Air Force, and the Air Training Command, especially DCS/Technical Training, the Training Development Directorate, and personnel at the Keesler School of Applied Aerospace Sciences. It is part of Rand's continuing research effort in the areas of planning and management in education, education technology, and the cost and effectiveness of education systems.

This report describes the Resource Utilization Model, the component of MODIA that simulates course operations and reports on the flow of students through a course and the use of the resources specified by the planner. The report is directed toward both course designers who will be using MODIA and computer analysts whose tasks may include modifications and extensions to the model.

The series of MODIA reports includes:

R-1700-AF, *MODIA: Vol. 1, Overview of a Tool for Planning the Use of Air Force Training Resources*, Polly Carpenter-Huffman.

R-1701-AF, *MODIA: Vol. 2, Options for Course Design*, Polly Carpenter-Huffman.

R-1702-AF, *MODIA: Vol. 3, Operation and Design of the User Interface*, Polly Carpenter-Huffman, Ray Pyles, and Misako Fujisaki.

R-1703-AF, *MODIA: Vol. 4, The Resource Utilization Model for Instructional Course Design*, Margaret Gallegos.

R-1704-AF, *MODIA: Vol. 5, A User's Guide to the Cost Model*, Ronald Hess and Phyllis Kantar.

SUMMARY

This report provides a comprehensive introduction to MODIA (*M*ethod *O*f *D*esigning *I*nstructional *A*lternatives), a system for planning a training course that was developed to help the Air Force improve the management of training resources. MODIA is designed primarily for the use of the five technical training centers of the Air Training Command (ATC). These account for the bulk of technical training, which is a major Air Force activity in that about 25 percent of Air Force personnel graduate annually from formal courses at a cost of over $600 million.

Over a third of the 300,000 different course hours in the technical training curriculum are substantially revised or newly prepared annually. Thus, in the normal course of events, ample opportunities arise for improvement of the management of training resources.

MODIA is a systematic process for planning the mix of students, instructors, materials, equipment, and facilities and the procedures by which all of these elements work together to effect student mastery of the subject matter. MODIA helps planners to create a detailed description of course operation and to derive an estimate of course cost consistent with the description. This encourages planners to devise and compare alternative plans for training courses.

The Resource Utilization Model (R.U.M.) is a computerized, discrete event simulation of course operations for resource planning. The model simulates resource demand, resource allocation, and student queueing generated by student progress through the potentially complex flow patterns of an instructional course. It can optionally include the stochastic or deterministic generation of arrivals, classification of students, failures, and rates of progress. Another MODIA component, the User Interface,[1] allows the planner to generate alternative course designs. Each such design, created by the user interactively with the User Interface, generates input for simulation of the course by the Resource Utilization Model. The model then supplies reports on student flow bottlenecks and resource utilization in terms of actual resource hours used, average student throughput times, and other information essential to planning. The planner may then use the Cost Model[2] to determine the total course costs of one or more alternative course designs. This is expected to be an iterative process. Validation of the model was done by the USAF School of Applied Aerospace Sciences at Keesler AFB, Mississippi, and is documented in an ATC Project Report dated July 30, 1976.

[1] See Polly Carpenter-Huffman, *MODIA: Vol. 2, Options for Course Design*, R-1702-AF; and Polly Carpenter-Huffman and Ray Pyles, *MODIA: Vol. 3, Operation and Design of the User Interface*, R-1703-AF.

[2] See Ronald Hess and Phyllis Kantar, *MODIA: Vol. 5, A User's Guide to the Cost Model*, R-1704-AF.

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I. INTRODUCTION

In planning a new course or modifying an old one, a course designer must consider many factors that will affect the time and other resources required to teach the course. These must be weighed against qualitative judgments as to the efficacy of certain teaching methods. Additional requirements and limitations will be placed on the course design by institutional policies and cost considerations. Complexity of the course planning task is increased as the available options increase. However, even within seemingly rigid planning constraints, many alternative course design possibilities may preclude the careful examination of each of them for their resource and time implications.

MODIA is a set of tools designed to assist in the course planning process. The computerized components of MODIA as shown in Fig. 1 consist of:

1. *The User Interface:* An interactive, branching questionnaire that elicits a tentative course design from the user. This tool assists the planner in expanding course objectives into a series of sequential learning events. A full course description, including the teaching strategy for these learning events, is developed by the planner and is the product of an interactive session with the User Interface.
2. *The Resource Utilization Model:* An event driven model[1] that simulates the operation of the course over time and produces detailed reports on resource utilization and demand as well as student flow patterns—wait and throughput times. This model may be used in a completely deterministic fashion or it may generate stochastic events based on sampling from random number streams to simulate the inexact nature of such events as arrivals, assignment of ability levels, and other parameters. The Resource Utilization Model takes the User Interface output as input.
3. *The Cost Model:* Provides total course costs, including personnel costs and resource life-cycle costs, given unit costs and maintenance factors from the planner.

These tools are intended to be used iteratively to examine and improve certain course design tradeoffs. They may be used for the design of new courses or for the redesign of existing courses. This report describes the Resource Utilization Model. It deals with other MODIA components only insofar as necessary for an appropriate context. Sufficient depth is provided to permit installation and use at a selected Air Force base. MODIA is a prototype research tool to be reviewed and possibly modified, or reproduced in production form by the client; therefore this report does not dwell on implementation-specific details.

Section II describes the process being modeled and the model. The model description includes a general discussion of model assumptions and inputs provided by the planner through the interface.

Section III defines each output variable in detail for reference use. Output variables are presented in the order in which they appear in the output reports.

[1] The model is coded in Simscript II.5, a proprietary language system of Consolidated Analysis Centers, Inc. (CACI), Los Angeles, California.

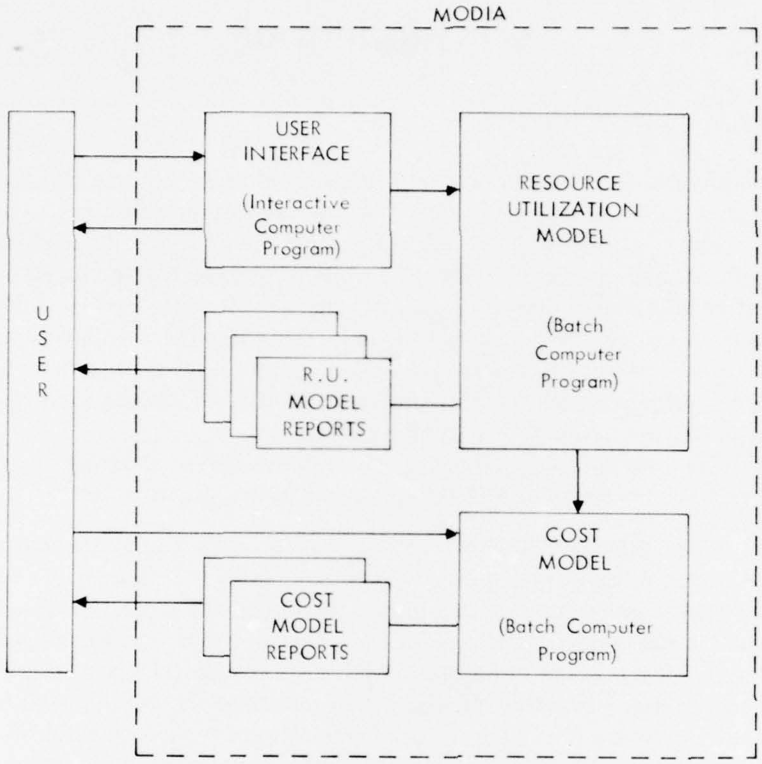

Fig. 1—Interactions between user and modia components

Sample simulation output reports are given. An understanding of this section is necessary to the use of the Resource Utilization Model.

Section IV discusses the sample case developed in earlier reports in the series and gives some guidelines for interpretation of the Resource Utilization Model output reports.

Section V provides the input specifications as required by the Resource Utilization Model from the User Interface. The MODIA user will generate this input automatically through the User Interface. The course and its characteristics are given from the viewpoint of the Resource Utilization Model.

Section VI briefly discusses model limitations and related assumptions. Limitations are described relative to the discussion in the preceding sections.

Section VII provides program documentation including call trees and descriptions of each routine.

Appendix A is the Preamble of the simulation code, and it defines all of the data structures to be used in the program. Comments in the Preamble are delimited by quotation marks (") or end of line, as required by Simscript II.5 conventions.

Appendix B contains the output reports for the sample case.

II. THE MODEL

PROCESS DESCRIPTION

The process being modeled is the progression or flow of students through a representative or composite technical training course. The focus is on the elements of technical training that reflect currently widespread practices and policies in Air Force training and on areas for potential change. The major elements of the process are:

- Student population,
- Course,
- Resources required for the course, and
- Decision rules for student flow and resource allocation.

The parts of the process that take place outside normal instruction time are not included in the model of the process. For example, time scheduled for meals or "coffee breaks" is omitted. Also omitted are all student activities that do not relate directly to course work, such as institutional orientation sessions, unscheduled homework, or "free" time.

Generally stated, the process consists of the following:

Students enter a course at random or deterministic time intervals.

They progress through a series of sequential learning events that constitute the course.

Resources of different types are required to teach the learning events in the course.

Students may be matched to learning events so that the particular subset of sequential learning events taken by each student may be varied according to student characteristics. For example, students already knowledgeable in a certain area might skip that learning event in a course.

The progression from one learning event to the next may be temporarily blocked by the unavailability of resources or of other students with whom to take the learning event.

Students may fail the course. Students may recycle all or parts of the course.

The time it takes a student to complete a learning event may be determined by a fixed time specification or may be affected to some extent by the student's ability.

The time it takes a student to complete the course is equal to the sum of the time spent in learning events and the time spent waiting for resources or other students.

This general process is modeled by a set of interrelated events that drive the model. The model is kept general and allows the planner to test many variations of the decision rules. The planner also provides, and may modify, the detailed specification of the course, the student population, and the resources to be simulated.

MODEL DESCRIPTION

Time

The model represents time as a continuing stream of course hours during which students may make demands on course resources. There are no course days, as such, in the R.U.M. The user will be required to specify the length of a course day for cost model purposes; however, this has no effect on the R.U.M., which operates only in course hours.

To illustrate the relationship between course day and calendar day, consider an R.U.M. status report produced at the 20th hour of simulated time—i.e., at time = 20.0 course hours. If the length of the course day is five hours, this report covers the first four calendar days of the course. If the course day is six hours long, the report shows course status at the end of the second course hour of the third calendar day.

Student Population

The students will be assigned individual ability levels drawn from a normal distribution with a mean of 1.0 and a standard deviation of .14. These may be used as surrogates for ability by the planner or they may be ignored. In the latter case all students are considered to have equal ability for course purposes. For example, at the planner's option, in learning events selected for individual instruction, students may be allowed to progress at a pace that is inversely proportional to their abilities: Students with more ability take less time and vice versa. A student with an ability level of 1.20 will complete such a learning event in 83 percent of the average time allowed (1/1.20 = .83). A slower student with an ability level of, say, .80 will take 125 percent of the average time allowed (1/.80 = 1.25). The planner may also impose an upper or lower boundary on the time allowed in such a learning event to avoid extremes or to account for factors other than ability.

The students may also be assigned an other-characteristic flag to indicate the possession or lack of some special characteristic. For example, students may be classed as having previous electronics training or no previous electronics training. The characteristic is defined by the planner, if used.

These attributes of the population are not essential to the model. However, their absence eliminates many possible teaching strategies based on some degree of population stratification. If it is not possible to identify those students with superior ability, it will be impossible to vary course content and teaching method for these students.

The Course

The course can be described as a series of sequential learning events. Through the User Interface the planner has divided the course into a number of learning events. This division may be gross at first and more detailed in later design iterations. The planner will declare a number of parameters for each learning event. These parameters will determine operational strategy for this part of the course. For example, each of these learning events takes some time to complete. This time parameter can be specified as a fixed interval regardless of student ability or it may be a range of time intervals.

Each learning event may be characterized as being suitable for students of all or some ability levels and suitable for students with or without the "other characteristic." For example, a learning event might be characterized as suitable only for students of average ability (or less) with previous electronics training.

Some learning events may be characterized as tests. Tests may be specified as failable or non-failable. There is no limit to the number of tests specified.

"Section" is used with two meanings. A section of a learning event refers to the group of one or more students who will take a particular instance of that learning event together. A section waiting for resources has this static meaning. A section of a learning event is also an occurrence of that learning event. That is, the learning event occurs when a section of that learning event is in progress. Many sections of a particular learning event may exist simultaneously; some or all of those sections may be concurrently in progress.

All sections of a particular learning event follow the specified characteristics laid down by the planner for that learning event. For example, the size (in terms of students) of a section can be specified in terms of a range—a minimum number required and a maximum number allowed. Alternatively, it can be specified as a fixed size by setting minimum equal to maximum. When a fixed size has been specified, all sections of that learning event will contain the same number of students. A section is not "formed" until at least the minimum number of students required have assembled.

The planner provides the learning events in the course in their proper sequential order. Students must take the learning events in that order. Not only will learning event 1 precede learning event 2, but once a learning event has begun, no student will be allowed to join it late. Instead the student must join a later section.

Resources

Resources are required for the duration of some or all of the learning events in the course. Each learning event has associated with it a set of resource types (e.g., instructor, classroom).

- A section (of a learning event) uses resource types in quantities that depend on (a) the number of students in a section when the section begins and (b) the capacities (in terms of students) of the resource types.
- Resource capacity is specified in terms of the number of students that one unit of a particular resource type can accommodate.
- The presence of other students may be an implicit requirement for a learning event. These students would not be part of the "required resources" set. Instead they appear as a requirement for a minimum number of students per section. The section will not be formed until this requirement is met.
- A resource type is named by the planner, and it is assumed that all units of this resource type are fully interchangeable for all purposes in the course. If this is not so, the planner must assign different names to those that are not interchangeable. Resource characteristics that can be specified by the planner are described more fully on p. 14.

Decision Rules

Student flow through the course will always be from first to last learning event. Student flow from one learning event to the next may be bypassed if the student's characteristics do not match those of the learning event.

Student flow through the course may be temporarily blocked if the minimum number of students required are not available to take the learning event or if sufficient resources are unavailable for the students in a learning event section.

Resources will always be assigned on a first-come-first-served basis. (No scheduling optimization will be done.)

When some of the resources required for a particular section of a learning event are not immediately available, those that are available are reserved for that section of the learning event and are held unavailable until the additional resources required are made available to the section.

When there are not sufficient resources to service all students who require them for learning events, the students wait until the resources are available (released).

Recycling is the selection at a test point of some percent of students to "wash back" to a previous point in the course. Students thus selected repeat course material from the washback point up to and including the test at which they were originally recycled.

The planner may specify the percent of students to recycle for each learning event designated by the planner as a test, regardless of whether the test is "failable." The planner may also specify a maximum number of times a particular student may be sent back from a particular test point. Failure is the selection of X percent of students for failure of the course. The selection takes place at a failable test. Students who fail drop out of the course immediately. Students who do not fail a test the first time they take it do not fail on subsequent recycles through the test point.

Test failures are specified by providing an overall course fail rate. Some or all of the tests may then be specified as "failable." If the student population is not stratified—that is, if it is considered as a single homogeneous group for course purposes—the course failure rate is distributed evenly over each failable test. In this case, the probability of failure at each test can be determined simply from the failure rate and the number of failable tests. This results (on the average) in a fixed percent of students failing each failable test. (Since student failures are simulated through the generation of random numbers, the fixed percent of failures reported in the early stages of simulation will only approximate the desired percentage. As more students take a failable test, this approximation will improve.) If the student population is stratified, the failure rate may be apportioned (by the planner) unequally across student categories. This is explained in more detail on p. 20.

Examples of the Process

In this example, a fixed arrival rate for students and a uniform fixed section size are assumed for every learning event in the course of ten students per section, and a fixed completion time is assumed for each learning event of one hour. For this course, the following is known:

- Time between arrivals (of groups of students) at the course (1 hour).
- How many students allowed in each section of a learning event (10).
- How long it takes to complete each learning event (1 hour).

If the arrival group size is a multiple of 10, the time between arrivals is one hour, and unlimited resources are assumed for this example, the throughput time per student = (the number of learning events in the course) × (one hour). It is also possible to determine the actual student load to expect in the course after the startup time is passed. (The startup time is the time preceding the first graduation from the course.) Figures 2a and 2b show a simplified model of part of this process. Figure 2a shows the logical flow of the model; Fig. 2b shows the events generated by this process.

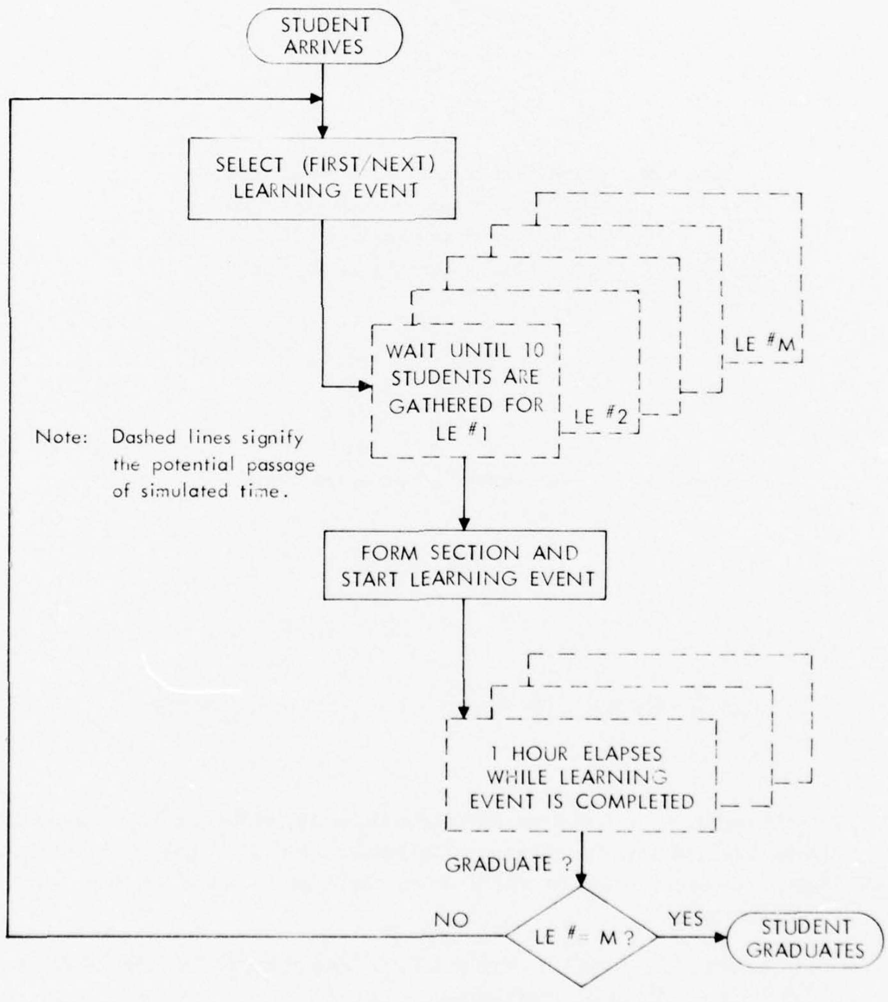

Fig. 2a—Student flow through M-learning event course example

Time = 0	10N students arrive
	N sections of Learning Event 1 start
Time = 1	N sections of Learning Event 1 complete
	N sections of Learning 2 start
	10N students arrive
	N sections of Learning Event 1 start
Time = 2	N sections of Learning Event 2 complete
	N sections of Learning Event 3 start
	N sections of Learning Event 1 complete
	N sections of Learning Event 2 start
	10N students arrive
	N sections of Learning Event 1 start
.	
.	
.	
Time = M	N sections of Learning Event M complete
	10N students graduate from the course
	N sections of Learning Event M-1 complete
	N sections of Learning Event M start
.	
.	
.	
Time = M + 1	10N students arrive at the course
.	
.	
.	

Fig. 2b—Events in an M-learning event course example

Under the assumed arrival-group sizes and section sizes for the learning events, the students need not wait for other students to achieve the required section size of 10. There are several ways in which there might be a wait of students for the required section size:

- If student arrival groups were not a multiple of the section size of the first learning event for all students;
- If the number of students completing a particular learning event [(number of such sections in progress) × (number of students in each section)] were

not always a multiple of the required section size of the next sequential learning event.

In this first example, changing the time between arrivals will affect only the total number of students in the course at one time but will not affect the rate of flow of individual students. Other sets of assumptions can cause the average time between arrivals to contribute to the average time it takes a student to complete the course—throughput time.

For simplification, resources and student characteristics have been alluded to briefly but have not yet been included in the model. By ignoring resources in the model it is possible to say that there will be an unlimited supply of resources and that student flow would therefore be unconstrained by resource availability. This is usually a valuable case to simulate. Assume, however, that measurements of resource use are of interest. For example, for any given set of assumptions, it might be desirable to know:

- The maximum number of units of a given resource type concurrently in use at any time in the course;
- For each resource type, the cumulative resource use hours at a particular time in the course—i.e., the time integral of the number of units in use;
- For each resource type, the percent of available resource time utilized—i.e., (the number of resource use hours for a particular resource type) / [(the maximum number or resource units in use) × (the number of total course hours simulated)].

To calculate these numbers the model requires specification of the number of different resource types to be used in the course. Then for each such resource type the capacity of one unit (in terms of students) and the learning events that require the use of that resource must be specified.

Assume a total of four resource types with capacities as shown in Table 1.

For the sake of simplicity further assume that this course consists of 30 learning events. Resource capacities, when combined with earlier course assumptions, will now have implications for course operations. Because sections will always have ten students, instructors of type B will always be used in sets of two per section. Similarly, five equipment sets per section will always be used where they are required. Instruction of type A and classrooms would be assigned one to a section wherever required. Further assume that students arrive in groups of 20. If every learning event in the course were to require the use of each of these resources, the resource use measurements could easily be computed from the course load and the selection of some arbitrary number of course hours greater than or equal to the time required for the first students to graduate from the course. For example, compute these measurements for 300 course hours; first the maximum number of units concurrently in use for each resource type:

- Course load under the above assumptions = 30 learning events each with 20 students (30 × 20) = 600 students, once the new course reaches a steady state (for this case, any time after time = 30.0 course hours).
- For resource types 1 and 2 (classroom and instructor type A) the maximum number of units in use

$$= \frac{\text{600 students}}{\text{section size 10}} = \text{60 sections}$$

Table 1

SPECIFICATION OF RESOURCE TYPES AND THEIR CAPACITIES

Resource Type	Name	Capacity	(Students per Unit)
1	classroom	10	(students per classroom)
2	instructor type A	10	(students per instructor)
3	instructor type B	5	(students per instructor)
4	equipment set	2	(students per equipment set)

(with 1 resource unit per section) = 60 units. For resource type 3 (instructor B) there will be two units (instructors) per section, or 120 instructors, etc.

Second, the total number of resource use hours for each resource type:

- At time 30.0 (course hours) the number of resource use hours each for resource types 1 and two will be

  $$2i = 930 \text{ use hours},$$

  where 2i represents two concurrent sections each one hour long, for each learning event started by the ith hour. Each subsequent course hour will then increment this sum by 60 resource use hours (steady state use).

  Using the 60 units per hour from the steady state calculation above and given 270 remaining hours in course, $270 \times 60 = 16{,}200 + 930 = 17{,}130$ total use hours for each of these two resources. Types 3 and 4 would be computed similarly.

- To calculate the percent utilization for resource type 1 at time 30.0 requires total available use hours or: (60 units) $\times$ (30 hours) = 1800 available use hours. Now,

  $$\frac{930 \text{ resource use hours}}{1800 \text{ available use hours}} = .516,$$

  or 51.6% utilization.

- At time = 300.0, the percent utilization for resource type 1 would again be calculated as resource hours or: 930 resource use hours during the startup time 0 to 30 plus 16,200 use hours during the next 270 hours for a total of 17,130 use hours, divided by 60 units available over 300 hours, or 18,000 total available resource hours.

  Therefore,

  $$\frac{17{,}130 \text{ resource use hours}}{18{,}000 \text{ available use hours}} = 95 \text{ percent utilization.}$$

For this case, the utilization rate of resources would approach 100 percent as the effects of the long startup time become less significant compared with the total time over which resources are used—that is, with course

length. Further, since the 30th hour of the course there has actually been short-term utilization of 100 percent. That is, the number of hours available equalled the number of hours used. Since courses with startup and winddown times are of concern rather than permanent courses, the calculation method reflects the costs of operation of such courses—i.e., the total, long-term resource utilization over the course time.

For the purposes of this illustration unlimited resources are assumed to be available for course use. This is a valuable case to examine because it results in the computation of the number of resource units required for a particular set of design assumptions given that *no waiting for resources* is to be tolerated. If resource costs are very high compared with student time, limiting resource units to some smaller quantity that would require student wait times becomes a desirable condition to simulate. Similarly, a course for which only an already existing and limited set of resources will be available could be simulated. Figure 3 shows the incorporation of decision rules for the allocation of resources. The events generated would remain the same as long as resources are not actually limited. Figure 4 shows the events generated by this model of the process if there are only enough resources for one section at a time; that is, the total available number of classrooms is limited to one, instructors of type A to one, instructors of type B to two, and the equipment sets to five. This is an unlikely planning decision given the assumptions on arrival rates etc. and is done only for the sake of example.

The resource utilization in this case is 100 percent. That is, (the sum of hours in use)/(total available use hours) = 1.0. The average course throughput time per student is, of course, increasing without bound. This case is extreme and is shown merely to illustrate the basic queueing process of the model.

Resource demand, allocation, and utilization are quite straightforward in the cases so far presented. The model is clearly unnecessary for such cases, and they can be hand-computed easily. The kind of case to which the model is necessary for resource use measurements would use the planning options that allow variety and flexibility in the course design. For example, with an arrival rate of ten students (plus or minus five) approximately every six hours (plus or minus two), the rate of flow could be strongly influenced by the requirement for a fixed section size greater than one. Instead assume students could move individually through all learning events of the course except tests, which would have a minimum section size greater than one.

Another level of complexity can be added through the specification of failure rates and the removal of the simplistic assumptions so far made with regard to resource use by learning event and completion times for learning events. Say that 10 percent of the students can fail the course, and 15 percent of all students who pass the second test must recycle back to the beginning of the course. Next, specify different combinations of resources for the learning events, depending on subject matter. Some learning events would require instructor type A, some B, some both, etc. The time to complete the learning events could be specified as a different range of times for different learning events. For example, the time allowed to complete learning event 1 might range from 30 to 60 minutes with the average time (45 minutes) taken by the average student (ability level = 1.0). The range might be different for learning event 2 etc. The time to complete tests or learning events with

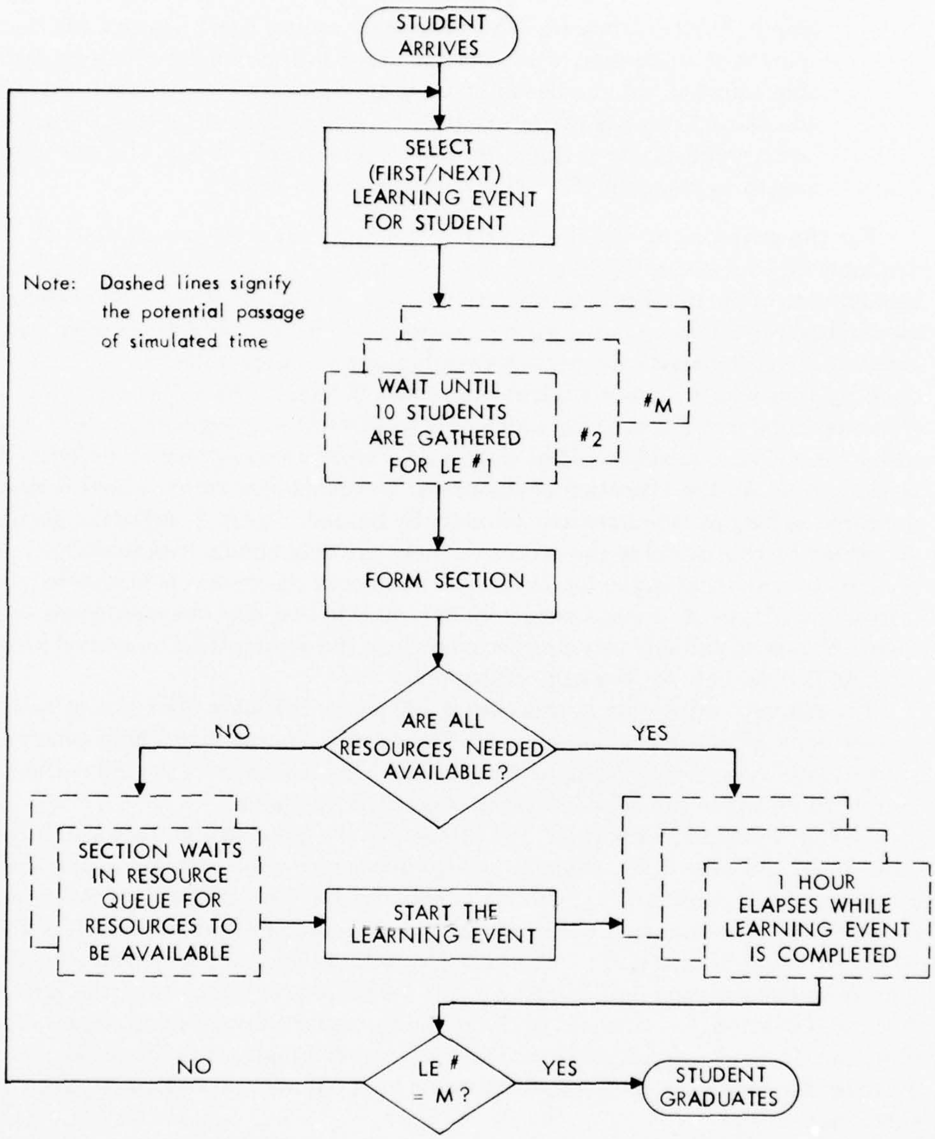

Fig. 3—Effect of resource requirements on student flow through course

Hours	Events
Time = 0	20 students arrive
	2 sections of Learning Event 1 are created
	1 section gets the resources and starts the Learning Event
	1 section is queued to wait for release of the resources
Time = 1	1 section completes Learning Event 1 The resources are released and the section waiting for the resources gets them.
	The de-queued section starts Learning Event 1
	The completing section waits for the resources in order to start Learning Event 2 (remember all Learning Events in our examples require the same resource sets).
	20 students arrive
	2 more sections are created. Both sections join queue for resources needed for Learning Event 1. They are 2nd and 3rd in the queue.
Time = 2	1 section completes Learning Event 1 The resources are released and the section waiting at the front of the queue gets the resources.
	The de-queued section starts Learning Event 2
	The section completing Learning Event 1 joins the queue for resources for Learning Event 2 (this section is now third in the queue).
	20 students arrive
	2 more sections are created
	Both sections join the queue for resources (as 4th and 5th in queue)

Fig. 4—Effect of resource requirements on events of course

a section size greater than one would be fixed but different for each such learning event—for example, one hour for test 1, 30 minutes for test 2, etc.

In the terminology of queueing theory, the arrival process, the service process, and the complexity of the decision rules used in this kind of case are not amenable to analytical solution. Moreover, given the variety of options specified, most planners would agree that this case does not lend itself to manual simulation. In addition, the process would have to be repeated in its entirety for most course variations. Computerization of this process alleviates its most humdrum requirements: the stepping through the logical sequence of events and noting the change at each step.

Figure 5 shows the model sequence with the addition of a few more decisions for queueing of students for resources or for students.

Resource Characteristics

To better understand the first condition of test 2 in Fig. 5 it is necessary to examine resource characteristics treated by the model in more detail. Each resource type specified for a course design by the planner may be given a name for identification. In addition, resources can be described by three characteristics that determine the manner of their allocation to sections of learning events. Those characteristics of the resource are its:

- Shareability (across sections of learning events),
- Capacity (students per unit), and
- Quantity to be simulated as available for course use.

Shareability

A resource type may be considered shareable or it may be considered dedicated. Shareable means that any fractional capacity of a unit of the resource that is available for use is available to students who are in the same or in different sections of one or more learning events. If the capacity of a resource type is two students and it is shareable, a single unit of that resource may be allocated to two students in two different sections (of possibly different learning events during the same time period or overlapping portions of it). Having the characteristic shareable does not, however, guarantee sharing and may result in a unit that is half in use and half available for a given time period. If a resource type is dedicated, then it is assumed that its unused portions are available only to students in a single section of a learning event. Resources are thus always acquired for such a section in integral units.

A resource type may be shareable or dedicated over the entire course or its shareability may vary by function or use and thus by learning event. When the sharing policy for a resource type is varied over the course, the unused fractional portions of a unit are available for sharing only across sections of learning events that consider the resource shareable. Learning events that consider the resource dedicated will not be assigned portions of a unit while it is in "shareable" use. Shareable resources should be fully accessible to all sections sharing them. The model assumes that such resources are either remotely accessible to all sharing students or that the resources and the students are all centrally located. In the

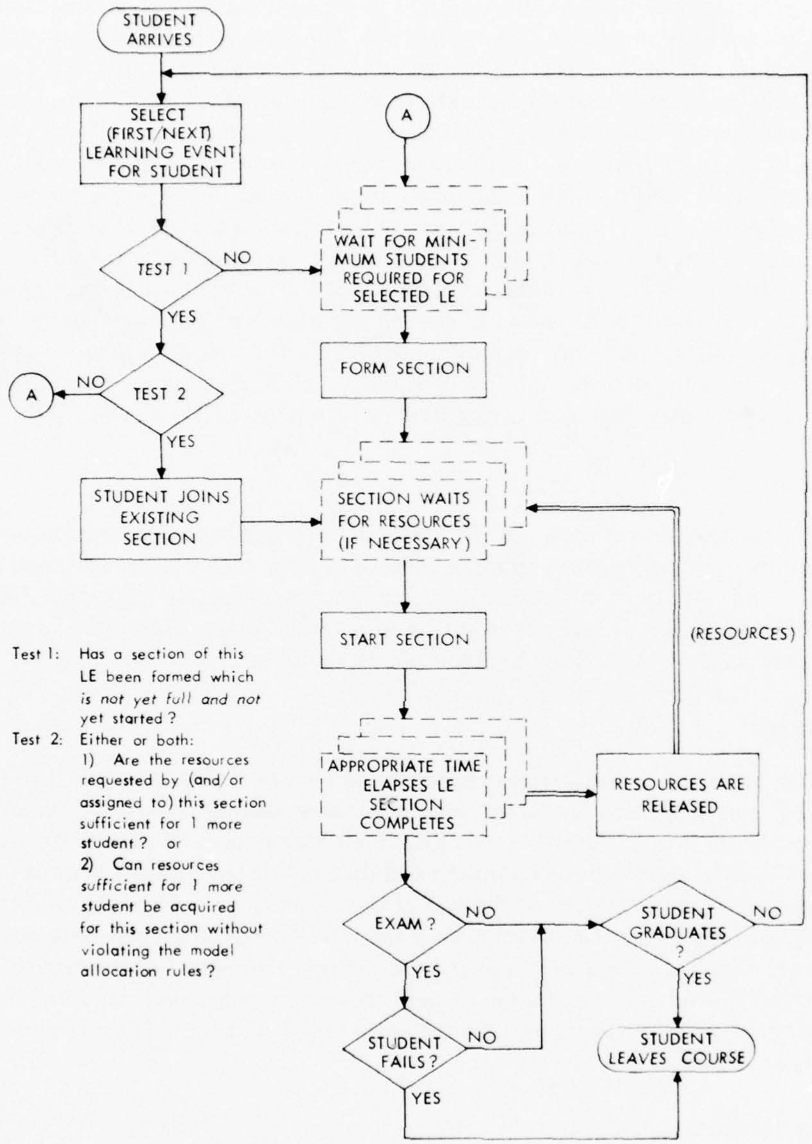

Fig. 5—Student flow with variable course parameters and exams

latter case, any other dedicated resources being used with the shareable resources must, of course, be portable to the central site. The allocation of shareable resources does not guarantee that the section using some fraction of a unit will have the allocation made from a single unit. For example, a section using half the capacity of a time-sharing computer may actually be assigned one-quarter capacity of each of two computers. Because of the way shareable resources are allocated, it is best not to simulate their use unless the total amount of resource capacity required and its availability are all that is important to the section. If three units of a shareable resource are being shared equally by six sections, the three units will shrink to one when four of the sections complete, regardless of the order in which fractions of the units were allocated or the order of the allocations or completions. That is, half of a unit plus half of a unit always equals one full unit. No attempt is made to ascertain whether this should be considered two units each half in use or four units each one-quarter in use. Rather it is assumed to be one unit fully in use.

Capacity

The specification of capacity of a resource type has been discussed in terms of the number of students one unit can serve. Capacity may also be specified at the course level or may be varied according to function or use by indicating different capacities for different learning events. For example, a large classroom might have a student capacity of 100 for lectures and 50 for tests.

Quantity

The quantity the planner desires to simulate as available for course use can be derived from available inventory plus purchases deemed necessary for a given course design. It is also possible to approximate this requirement by setting all the quantities to be simulated as unlimited and then noting the number of units of each resource type in the system at the end of the selected number of course hours. If the quantities are specified as unlimited, the model simulates instantaneous acquisition of resources as they are needed; thus, the resource demand generated by each resource type for a given course design can be approximated. If quantities are specified they will be considered limited as specified, and no instantaneous acquisition is simulated.

Other Model Interaction

At the option of the planner, students may be assigned to one of two, three, or four categories. This stratification may be based on ability levels or on the possession or lack of a special student characteristic, if the planner has defined one. The Guide to the User Interface provides a number of examples of such stratification. This option allows the planner to specify the percent of the population to be treated as slow, average, fast, etc. to match students to learning events. That is, portions of the course may have been designed for particular portions of the student population, and these student category names allow a matching of course to student.

To illustrate the effect of this option on failures and tests assume that a planner decides that 75 percent of the student population is slow-average and 25 percent are fast. The failure rate chosen for the course is 5 percent. The planner may let

the failing population reflect the entering population or not. For example, to reflect the entering population the failing population would contain 75 percent slow-average students and 25 percent fast students. Alternatively, the failing population may all come from the slow-average category or it might contain 90 percent category 1 students and 10 percent category 2 students.

The following illustrates the interaction of this option with other model features. If a course had two failable tests and students in category 1 were eligible to take both tests, but students in category 2 could only take one test, the failure rate computed for category 1 students would be distributed over both tests while that computed for category 2 students would be concentrated on just the one test.

III. OUTPUT REPORTS AND OUTPUT-VARIABLE DEFINITIONS

This section defines output variables and describes in detail how each such variable is computed and, where important, the implications of the method of computation on the interpretation of model output. An understanding of this section is basic to the use of the model.

The organization of this section closely follows that of the output reports provided by the Resource Utilization Model. These reports are presented in the order in which they appear in the computer output generated by the model. Each output variable is described under the report heading in which that variable is found in the output. Variables will be referred to by the column heading that identifies them in the output report.

The first part of this section deals with the Recap Reports, which are provided at the beginning of all simulation output. They recapitulate the input received from the User Interface by the Resource Utilization Model. The planner has provided this input interactively and should review it carefully before going on to the actual output from the simulation. The second part of this section will cover the reports generated by the Resource Utilization Model as a result of the simulation of the course over time. These reports are printed at course hour intervals specified by the planner through the User Interface.

RECAP REPORTS

There are five Recap Reports. They always precede all model output. Since the reports are produced before the start of the simulation run, there is no time associated with them. All other model reports will have as their first output variable the time the report was produced, in course hours. The Recap Reports are as follows:

1. The summary of initial conditions (including student population stratification) in two parts;
2. The course to be simulated;
3. The resource types to be used;
4. The resources required by learning event; and
5. The cross reference table of learning events by resource type.

Recap Report 1. Summary of Initial Conditions

Table 2 is an example of this report. The first line tells how often simulation output reports will be printed. This time is reported in course hours.

The second line tells when the model run will be ended. Two options are available; the simulation will end either after a specified number of hours or after a specified number of students have graduated from the course.

Table 2

RECAP REPORT 1: SUMMARY OF INITIAL CONDITIONS—PART 1

```
REPORTS:  REPORTS WILL BE PRINTED EVERY   30.00 COURSE HOURS.

SIMULATION TERMINATION:  SIMULATION OF THE COURSE WILL TERMINATE AFTER 300.00 COURSE HOURS.


STUDENT ARRIVALS AT COURSE:
    APPROXIMATELY    5 STUDENTS (PLUS OR MINUS   3 STUDENTS) WILL ARRIVE AT THE COURSE EVERY    6 COURSE HOURS.


STUDENT GROUPING POLICY:

    STUDENTS WILL BE ASSIGNED TO 1 OF 4 CATEGORIES:

   CATEGORY    PERCENT   CATEGORY
   NUMBER      STUDENTS  COMPOSITION
   ------      --------  -----------

    1           .24      SLOW STUDENTS WITHOUT PROG.EXP
    2           .06      SLOW STUDENTS WITH    PROG.EXP
    3           .56      FAST STUDENTS WITHOUT PROG.EXP
    4           .14      FAST STUDENTS WITH    PROG.EXP


COURSE.FAILURE POLICY:

 80.00 PER CENT OF THE STUDENTS ENTERING THIS COURSE WILL COMPLETE IT SATISFACTORILY.   20.00 PER CENT WILL FAIL.


STUDENT FAILURES WILL BE RELATED TO STUDENT CATEGORIES AS FOLLOWS:


     30.0 PER CENT OF THE FAILURES WILL BE FROM CATEGORY 1 (WHICH CONTAINS  24.00 PER CENT OF THE STUDENT POPULATION).
     10.0 PER CENT OF THE FAILURES WILL BE FROM CATEGORY 2 (WHICH CONTAINS   6.00 PER CENT OF THE STUDENT POPULATION).
     60.0 PER CENT OF THE FAILURES WILL BE FROM CATEGORY 3 (WHICH CONTAINS  56.00 PER CENT OF THE STUDENT POPULATION).
      0.  PER CENT OF THE FAILURES WILL BE FROM CATEGORY 4 (WHICH CONTAINS  14.00 PER CENT OF THE STUDENT POPULATION).

****************************************************************

                    SUBJECT MATTER CODES
                    --------------------
 1.  EASY FACTS AND CONCEPTS
 2.  DIFFICULT FACTS AND CONCEPTS
 3.  SIMPLE CLASSROOM SKILLS (SELECTED RESPONSE)
 4.  SIMPLE CLASSROOM SKILLS (CONSTRUCTED RESPONSE)
 5.  COMPLEX CLASSROOM SKILLS (SELECTED RESPONSE)
 6.  COMPLEX CLASSROOM SKILLS (CONSTRUCTED RESPONSE)
 7.  TEAM SKILLS WITH SPECIAL RESOURCES
 8.  INDIVIDUAL SKILLS WITH SPECIAL RESOURCES (PRODUCT ONLY)
 9.  INDIVIDUAL SKILLS WITH SPECIAL RESOURCES (PROCESS ONLY)
10.  INDIVIDUAL SKILLS WITH SPECIAL RESOURCES (PRODUCT AND PROCESS)

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The next item will tell the user what kind of a student arrival pattern will be simulated.

If students will be categorized by ability or other characteristic, the stratification policy elected by the planner will be described in the next item. That is, the proportion of total students that compose each category along with the definition of each category will be given. Course failure policy will be spelled out.

If a student stratification policy has been elected and if the failure rate (see course failure policy above) is greater than 0, then the combination of these options will be shown. For example, in Table 2, the stratification policy has resulted in four categories of students. The course-wide failure rate is 20 percent. In this example it was elected not to have the failing population be an exact reflection of the entering population: No students from category 4 (fast students with programming experience) will fail, and 30 percent of the failures will come from students in category 1. The simple failure rate by group, for any category, is calculated as

$$\text{SIMP.FRBG} = \frac{\text{FAILRATE} \times \text{FGRP.SIZE}}{\text{GRP.SIZE}}$$

where FAILRATE is the total course failure rate (20 percent); FGRP.SIZE is the proportional representation of the category (category 1) in the failing population (30 percent), and GRP.SIZE is the proportional representation of the category in the total population (24 percent). This yields a failure rate of 25 percent for category 1. An easier way to see that this reflects what the tables show is to limit the entire student population to 100. Then 30 of these students will belong to category 1, and 20 students will fail the course; 30 percent of those failures (six students) will be category 1 students. If six students out of the 24 in category 1 fail, that group has a fail rate of 25 percent (one out of four).

If there were only one failable test in the course for which category 1 students were eligible, the probability of failure for these students at that test would be .25. With more than one failable test, the failures must be spread equally over the number of such tests to result in the desired overall course failure rate for the category. (This is analogous to grading on the curve at each test, with a particular category failing the same percent at each test.) This example will have two failable tests for category 1 students and the probability of failure at each test is given by

$$1.0 - (1.0 - \text{SIMP.FRBG})^{1/\text{NFTG}}$$

where SIMP.FRBG is the overall course failure rate for category 1 students calculated earlier (.25) and NFTG is the number of failable tests for these same students (2). See Table 3 below for a listing of failable tests for each category of students.

The probability of failure at each of those tests for category 1 students will be

$$1.0 - (1.0 - .25)^{1/2} = .1339$$

This last calculation must take into account that the population of category 1 students still around to take subsequent tests (after each failable test) is diminishing. Assume a total population of 100 students, a failing population of 20 students, and six of the failures from category 1. If 13.39 percent of the 24 category 1 students who take test one fail, 3.21 students have failed. Then 24 − 3.21 = 20.78 students are still around to take test two. Again, 13.39 percent of them fail, and there are

then 2.78 failures for a total of 5.9 = 6.0 student failures from category 1. This is an example of how such a probability of failure would average the desired number of students failing from each category and is not meant to suggest that it is possible to fail a fraction of a student in either the model or the process. Similar calculations are made by the model for each category.

The precise probability of failure by student category for each failable test is not reported to the user. The above discussion is given mainly to illuminate the underlying assumptions made about the process and used in the model: The failing population can be composed of different proportions of student categories than the entry population; the probability of failure at any given test may be different for students from different categories (at the option of the user); and each category may be "graded" for test/fail purposes on the same or different curves with the same or different cutoffs.

Part 2 of the Summary of Initial Conditions Report (Table 2) gives a list of the subject matter descriptors and their related subject matter codes. These codes will be used in later model reports where the length of the descriptors precludes their being printed out in full. They are provided here as reference only. Although "homework" is shown as a subject matter type, such learning events must have an elapsed time of 0.0 and must require no resources since they are not simulated.

Recap Report 2. Course To Be Simulated

Table 3 lists learning events in the course by number along with important characteristics.

L.E. NO.: The learning event number.

OBJECTIVE: The name of the objective of which this learning event is a part.

SUBJECT MATTER CODE: A numerical code for the subject matter definitions given in the last part of the Recap Report 1 (Table 2).

EVENT DESCRIPTOR: The event descriptor associated with this learning event. Possible descriptors available are:

- Presentation
- Guided Practice
- Unguided Practice
- Discussion
- Check Practice
- Homework
- Review
- Test

These are defined in R-1701-AF, *MODIA: Vol. 2, Options for Course Design.*

ELIGIBLE CATEGORIES: This column may have up to four sub-columns with the numbers 1, 2, 3, and 4 listed in these locations. If sub-column 1 contains a 1 under eligible categories, category 1 is eligible to take this learning event (and similarly for categories 2, 3, and 4). In Table 3, all four categories are eligible to take every learning event; however, any combination of categories is ac-

Table 3

RECAP REPORT 2: COURSE TO BE SIMULATED

L.E. NO.	OBJECTIVE	SUBJECT MATTER CODE (SEE P.2)	EVENT DESCRIPTOR	CATEGORIES ELIGIBLE	MAX. STDTS. ALLWD.	MIN. STDTS. REQD.	(HRS.:MINUTES) MAX. TIME ALLWD.	AVG. TIME ALLWD.	MIN. TIME ALLWD.	FAIL-ABLE?	PERCENT STDTS TO RECYCLE	RECYCLE TO L.E. NO.	MAXIMUM RECYCLES
1	CONCEPTS	1	PRESENTATION	1 2 3 4	15	3	2: 0	2: 0	2: 0		0.	0	0
2	CONCEPTS	2	PRESENTATION	1 2 3 4	15	3	0:30	0:30	0:30		0.	0	0
3	CONCEPTS	2	TEST	1 2 3 4	1	1	0:15	0:15	0:15	YES	10.00	2	1
4	FLOWCHRT	4	PRESENTATION	1 2 3 4	15	3	1: 0	1: 0	1: 0		0.	0	0
5	FLOWCHRT	4	GUID. PRACT.	1 2 3 4	1	1	1: 0	1: 0	1: 0		0.	0	0
6	COMMANDS	1	PRESENTATION	1 2 3 4	15	3	1: 0	1: 0	1: 0		0.	0	0
7	COMMANDS	1	TEST	1 2 3 4	1	1	0:15	0:15	0:15		30.00	6	4
8	CODING	10	PRESENTATION	1 2 3 4	15	3	1: 0	1: 0	1: 0		0.	0	0
9	CODING	10	UNGUID.PRACT	1 2 3 4	1	1	3: 0	3: 0	3: 0		0.	0	0
10	CODING	10	CHK. PRACT.	1 2 3 4	1	1	1: 0	1: 0	1: 0		0.	0	0
11	DEBUG	10	PRESENTATION	1 2 3 4	15	3	0:30	0:30	0:30		0.	0	0
12	DEBUG	10	UNGUID.PRACT	1 2 3 4	1	1	2: 0	2: 0	2: 0		0.	0	0
13	DEBUG	10	TEST	1 2 3 4	1	1	0:30	0:30	0:30		50.00	11	2
14	METHODS	10	PRESENTATION	1 2 3 4	15	3	1: 0	1: 0	1: 0		0.	0	0
15	METHODS	10	UNGUID.PRACT	1 2 3 4	1	1	3: 0	3: 0	3: 0		0.	0	0
16	METHODS	10	CHK. PRACT.	1 2 3 4	1	1	1: 0	1: 0	1: 0		0.	0	0
17	METHODS	10	TEST	1 2 3 4	1	1	1: 0	1: 0	1: 0	YES	50.00	14	2

ceptable. When the planner has not elected stratification of students, all learning events should show category 1 (only) under eligible categories, because in the absence of stratification all students are assigned to category 1.

MAX.STDTS.ALLWD.: The maximum number of students allowed in one section of the learning event. Once this maximum has been reached for a particular section, students desiring to join a section of this learning event will be required to start a new section.

MIN.STDTS.REQD.: The minimum number of students required to start one section of this learning event. Students arriving at a learning event must first attain this minimum before a section is formed that can attempt to obtain resources. Where MAX.STDTS.ALLWD. = MIN.STDTS.REQD., section size will be fixed for that learning event. Otherwise, the section size may vary between the maximum and minimum, depending on the flow of students at the time the section starts.

MAX.TIME.ALLWD.: Defined for learning events with maximum section size of one only (MAX.STDTS.ALLWD = 1). This is the upper limit (in hours and minutes) on the amount of time allowed to any student in an individual section of this learning event. In any other cases, MAX.TIME.ALLWD. is ignored by the model regardless of what is shown in this column.

As explained in Sec. II, the actual time taken by a student in an individual learning event will be inversely proportional to that student's ability level within the constraints of the maximum and minimum times allowed. Since the student ability levels are drawn from a normal distribution with a mean of 1 and a standard deviation of .14, MAX.TIME.ALLWD. will impose the greatest constraint on variability of time when it is closest to the mean (AVG.TIME-.ALLWD.) and least as it reflects a time associated with three or more standard deviations from the mean (1.42 × AVG.TIME.ALLWD.).

AVG.TIME.ALLWD.: The planner specifies the average time a student should be allowed to complete this learning event, starting from the time the students in the learning event have all their resources available and actually start "work" to the time the learning event is completed. If more than one student is allowed in a section of the learning event (i.e., MAX.STDTS.ALLWD. > 1), average time allowed will always be a fixed time segment, and all students in a section will complete in that time. However, if this is an individual learning event (i.e., MAX.STDTS.ALLWD. = 1), this time will be taken as the mean of the normal distribution truncated at either end as required by MAX.TIME-.ALLWD. and MIN.TIME.ALLWD. In the latter case, individual student completion times would vary accordingly.

MIN. TIME ALLWD.: Minimum time allowed is analogous to maximum time allowed and will be interpreted again according to whether this is an individual learning event or a group learning event. It is the lower limit on time allowed to a fast student in an individual section of this learning event. Students whose ability level is higher than the average and who are in an individual learning event (MAX.STDTS.ALLWD. = 1) may take less than the average time allowed to complete this learning event. That time will also be

inversely proportional to their ability level above the average but may not be less than the minimum time allowed. If MAX.STDTS.ALLWD. is not equal to one, this time is not used by the model.

FAILABLE?: This column will usually be blank for most of the learning events in the course. It is used only for those learning events with an event descriptor of TEST. A yes in this column means the test can be failed by some students; a no that the test will not be failed by any of the students in the course.

PERCENT STDTS TO RECYCLE: This column refers only to learning events with an event descriptor type of TEST. For other event descriptors a zero will appear in this column. When the event descriptor is TEST, the number in this column is the percent of passing students who will be recycled back to the appropriate point in the course. For example, in Table 3, learning event 3 is a failable test with a recycle of 10 percent. This means 10 percent of the *passing* students will recycle, not 10 percent of the students who take the test. In this same table, learning event 7 is also a TEST, but a non-failable test. Here the passing students will equal the entering students, and 30 percent of all students who take this test will recycle to learning event 6. This is different from 30 percent of all students who take the course because some students were lost at the first test.

RECYCLE TO L.E. No.: This column is applicable only if PERCENT STDTS TO RECYCLE is greater than zero. In those cases this is the point in the course to which those students will recycle. In Table 3, recycling students from the first test will recycle to and repeat from the second event. Recycling students from the second test will repeat from learning event 6.

MAXIMUM RECYCLES: The maximum number of times any particular student will be sent back from a particular test. Where there are overlapping test domains in a course, a student might recycle some of the material more than the number of times indicated by MAXIMUM RECYCLES, but never more times than the sum of the MAXIMUM RECYCLES of the overlapping tests. For example, if learning event 10 is a test that may recycle a student to learning event 1 and learning event 20 also recycles a student to learning event 1 and each of these tests has a maximum recycle of 1, a student may recycle only from each test once and still cover the material in the first 10 learning events more than twice, yet never more than three times.

Although the model permits the user to specify different MAXIMUM RECYCLES values for different tests, the current version of the User Interface applies the same number to all tests in the course.

PERCENT STDTS TO RECYCLE is the probability that any passing student will recycle. Since recycling students are always passing students, the actual proportion of recycling to non-recycling students will be larger than this number and will depend on the maximum recycles allowed. For example, in Table 3, Test 1 has a percent students to recycle of ten and a maximum recycle of two; so 10 percent of the passing students will recycle once and 10 percent of the recycling students will recycle twice, for a total of 11 percent recycling students.

Recap Report 3. Resource Types To Be Used

This report specifies the name and identification number of each resource type to be used in the course (see Table 4). A resource type whose capacity is constant and can either always be shared or never be shared can be fully specified in this report. Resource types that will have a varying capacity or a variable policy with regard to their shareability can be fully specified only in a more detailed report, where resource types with such characteristics are defined one learning event at a time. The course-wide specifications for resources are given in this report.

RESOURCE NO.: The resource number that will identify this resource. Each resource type used in the course has one line.

RESOURCE NAME: The name of the resource. Where space allows, the resource name is usually used along with the resource number in subsequent reports.

QUANTITY (LIMITED/UNLIMITED): One of the next two columns of this report will have an X placed under it for each resource. An X under Limited indicates that the resource inventory will be limited to a fixed quantity during the entire simulation run. (That fixed quantity will be given under INITIAL QUANTITY ON HAND.) If the X is under Unlimited, the initial quantity on hand will be zero, and resources will be added to the inventory as they are needed. See Output Report 5, Resource Utilization by Resource Type, for a more detailed discussion.

INITIAL QUANTITY ON HAND: If the quantity of the resource was unlimited, this will always be equal to zero. Otherwise, initial quantity on hand will reflect the limited number of resources available during the simulation run of the course.

ACROSS-SECTION SHARING POLICY (FIXED/VARIABLE): A resource may be defined as dedicated to a particular section during its use or shareable among various sections of possibly different learning events that might be running concurrently. For some types of resources this sharing policy should be fixed for all learning events in the course—that is, the resource type should be dedicated or shared, regardless of which learning event it is used in. In this case, the across-section sharing policy will be declared fixed. For example, in Table 4, all of the resources except for CLSROOM (resource 7) have a fixed across-section sharing policy. Some are dedicated throughout, some shared throughout; only resource 7 will be variable and its shareability will be specified at the learning event level rather than at the course level. This latter specification is shown in Table 5, col. 4, where learning events that require the use of this resource define it sometimes as shared, sometimes as dedicated. It is occasionally desirable to allow a resource type to be considered dedicated for certain uses and shareable for other uses. In those cases, the across-section sharing policy would be variable.

CAPACITY PER UNIT (FIXED/VARIABLE): Capacity of the unit is defined in terms of students per unit—how many students one unit of this resource type can accommodate simultaneously. If the number of students the resource can accommodate is fixed, regardless of the use to which it is being put, by defini-

Table 4

Recap Report 3: Resource Types To Be Used

RESOURCE NO.	RESOURCE NAME	QUANTITY LIMITED/UNLIMITED	INITIAL QUANTITY ON HAND	ACROSS-SECTION SHARING POLICY FIXED/VARIABLE		CAPACITY PER UNIT FIXED/VARIABLE		CAPACITY (STUDENTS PER UNIT) IF FIXED CAPACITY
1	INSTR	X	0	DED		FIX		15
2	T.ASST.	X	0	SHR		FIX		5
3	PROG.TXT	X	0	DED		FIX		1
4	TESTER	X	0	DED		FIX		1
5	TERMINAL	X	0	DED		FIX		1
6	CARREL	X	0	DED		FIX		1
7	CLSROOM	X	0		VAR		VAR	
8	MONITOR	X	0	SHR		FIX		10

Table 5

RECAP REPORT 4: RESOURCES REQUIRED BY LEARNING EVENT

L.E. NO.	RESOURCE NO.	RESOURCE NAME	SHRD/DED	CAPACITY (STUDENTS PER UNIT)
1				
	1	INSTR	DED.	15
	7	CLSROOM	DED.	15
2				
	1	INSTR	DED.	15
	7	CLSROOM	DED.	15
3				
	4	TESTER	DED.	1
	7	CLSROOM	SHRD	10
	8	MONITOR	SHRD	10
4				
	1	INSTR	DED.	15
	7	CLSROOM	DED.	15
5				
	2	T.ASST.	SHRD	5
	7	CLSROOM	SHRD	10
6				
	3	PROG.TXT	DED.	1
	6	CARREL	DED.	1
7				
	4	TESTER	DED.	1
	6	CARREL	DED.	1
8				
	1	INSTR	DED.	15
	7	CLSROOM	DED.	15
9				
	5	TERMINAL	DED.	1
10				
	2	T.ASST.	SHRD	5
	7	CLSROOM	SHRD	10
11				
	1	INSTR	DED.	15
	7	CLSROOM	DED.	15
12				
	5	TERMINAL	DED.	1
13				
	4	TESTER	DED.	1
	6	CARREL	DED.	1
14				
	1	INSTR	DED.	15
	7	CLSROOM	DED.	15
15				
	5	TERMINAL	DED.	1
16				
	2	T.ASST.	SHRD	5
	7	CLSROOM	SHRD	10
17				
	4	TESTER	DED.	1
	7	CLSROOM	SHRD	10
	8	MONITOR	SHRD	10

tion the capacity per unit is fixed. If the number of students that can be accommodated depends on the function and upon the learning event in which the resource is used, the capacity per unit is considered variable. When the capacity is fixed it will be given in the last column. Whether it is fixed or variable, it is repeated by learning event in Recap Report 4. When the planner has left capacity of a resource type undefined, the model will show the capacity as one student per unit course-wide—fixed capacity = 1. This option is considered useful when a resource might be purchased with many differing capacity options. For example, a course design where a new facility was to be acquired might want to keep classroom sizes open until the best class (section) sizes for a particular teaching strategy were determined.

By examining various simulation model output variables on initial planning iterations, the course designer can explore the effects of varying section sizes in different parts of the course. As long as existing capacities are not constraints, there is no need to simulate them too early. With a capacity of one, the average number of students course-wide (in other learning events) who are using the resource can provide guidance for initial estimates of a workable capacity for a resource type. That is, the maximum number of umits in use by learning event can be used to estimate the section sizes that are achieved and, if available and desirable along other dimensions, units with such a section size capacity might be considerd. Naturally these initial runs should be followed up with more concrete specifications of capacity to examine their overall utilization.

CAPACITY (STUDENTS PER UNIT)—(IF FIXED CAPACITY): If the capacity of this resource is fixed, this column will show the number of students per unit this resource type can handle regardless of learning event. If the capacity is variable, the differing capacities will depend on the learning event and appear in the next report. Table 4 shows a resource type, CLSROOM, that has both varying capacity and varying sharing policy. This resource is fully specified in Recap Report 4 (Table 5).

Recap Report 4. Resources Required by Learning Event

This report (see Table 5) shows which learning events in the course will require the use of each resource type. The actual number of units used in a section of any learning event will depend on:

- The number of students in the section (at the time it starts),
- The capacities of the resources for purposes of that learning event,
- Whether the resources must be dedicated or may be shared with other sections.

These latter two characteristics are given for each resource by learning event. If the resource type in question was defined in a fixed manner at the course level, these will be repetitions of the information given in Recap Report 3. Otherwise, where the specification of a resource type is fully or partially variable, the information in this report is required to compute required resources for any particular learning event.

Column 1 gives the learning event number, column two the resource number, and column 3 the resource name. Column 4 tells whether this resource type is shared or dedicated for the purpose of this learning event. See across-section sharing policy (fixed/variable) in the Recap Report 3 for course-wide specifications of the shareability of this resource.

Column 5 gives the capacity of this resource type for purposes of this learning event in students per unit of the resource type. Note that CLSROOM (resource type 7) has been declared to have a capacity of 15 students in all those learning events where it is dedicated. The capacity has been reduced to ten students where the classroom is being shared among students in different sections—i.e., learning events 5, 10, 16 and 17.

Recap Report 5. Cross-Reference Table—Learning Events by Resource Types

This report (see Table 6) provides essentially the same information as that found in the preceding report. However, it is sometimes useful to see at a glance which learning events are using a particular resource. The first column gives a resource-number/name pair and then a line or lines containing the learning events (in sequential order) that use this resource.

Table 6

RECAP REPORT 5: CROSS REFERENCE TABLE—LEARNING EVENT BY RESOURCE TYPE

RESOURCE NO./NAME	LEARNING EVENTS WHICH USE THIS RESOURCE:
1 INSTR	1 2 4 8 11 14
2 T.ASST.	5 10 16
3 PROG.TXT	6
4 TESTER	3 7 13 17
5 TERMINAL	9 12 15
6 CARREL	6 7 13
7 CLSROOM	1 2 3 4 5 8 10 11 14 16 17
8 MONITOR	3 17

SIMULATION OUTPUT REPORTS

Reports generated by the Resource Utilization Model during the simulation of a course will be printed whenever course hours in the simulation equal a multiple

of the printing interval chosen by the user. For example, in the reports shown in this section the interval selected was 30 course hours. Therefore, printed reports were provided at time = 30:00, 60:00, 90:00 . . . course hours.

Simulated course time is printed in the upper left hand corner. (An additional final set of reports is also provided if the simulation end time is not an even multiple of the report interval.) The six reports generated are:

1. A Summary Report of Student Flow
2. Students and Sections by Learning Event Number
3. Student Queues by Learning Event Number
4. Resource Utilization by Learning Event
5. Resource Utilization by Resource Type
6. Sections Queued by Resource Type

Each of these reports will be treated individually below. A discussion of the interrelationship of various output elements is included as part of the individual definitions. It is sometimes necessary to look at more than one output report to determine the interpretation that should be given to an isolated output measure. For this reason it is important that the user be as familiar with a general discussion as with the definition of each output element.

Output Report 1. Summary Report

This report (Table 7) presents a summary of student flow through the course up to this time.

NUMBER OF ARRIVALS: Total number of students who have thus far arrived at the course.

NUMBER OF GRADUATES: The total number of students who have graduated from the course thus far.

NUMBER OF FAILURES: The total number of students who have dropped out of the course because they failed a test.

CURRENT NUMBER OF STUDENTS: The number of students who are currently in the course—i.e., the current course load.

The number of students + the number of failures + the number of graduates will always equal the number of arrivals.

AVERAGE TIME BEFORE FAILURE: The cumulative sum of total time in the course of each failing student (at time of failure) divided by the number of failures.

CURRENT STUDENTS RECYCLING: The number of students currently in the course who are in the process of recycling.

AVERAGE STUDENT LOAD: The integral over time of number of students in course divided by the total course time (total course time = the report time—i.e., now).

PEAK STUDENT LOAD: The maximum number of students concurrently in the course.

Table 7

OUTPUT REPORT 1: SUMMARY

NUMBER OF ARRIVALS	=	25
NUMBER OF GRADUATES	=	0
NUMBER OF FAILURES	=	3
CURRENT NUMBER OF STUDENTS	=	22
AVERAGE TIME BEFORE FAILURE	=	20:15
CURRENT STUDENTS RECYCLING	=	9
AVERAGE STUDENT LOAD	=	13.0
PEAK STUDENT LOAD	=	22.0

<<<< CATEGORIES >>>>

CATEGORY NO.	CUMULATIVE NUMBER OF STUDENTS ARRIVED /	FAILED /	GRADUATED	AVERAGE TIME TO FAILURE /	FINISH COURSE
1	5	1	0	29: 0	0: 0
2	2	0	0	0: 0	0: 0
3	16	2	0	15:53	0: 0
4	2	0	0	0: 0	0: 0

AVERAGE TIME TO FINISH COURSE: The cumulative sum of student throughput times (for those students who have graduated) divided by the number of students who have graduated. If no students have graduated at this time, this line will not be printed.

CATEGORIES: A table of numbers providing much of the above information, by category, if the planner has chosen student population stratification. Table 7 shows that of the 25 arrivals that have occurred by time = 30.0 course hours, five are in category 1, two are in category 2, 16 are in category 3, and two are in category 4.

Current students in each category can be computed by subtracting both the graduates and the failures from the arrivals, for that category. For example, since no students in category 2 have either failed or graduated, the four arrivals in that category are still in the course.

Average time to failure (or to completion) is shown for the total population in the list above and for each category in the tables below.

Output Report 2. Students and Sections by Learning Event Number

This report will print one line for each learning event in the course that has had at least one section of the learning event actually started at report time. Table 8

shows a report of a course at time = 30. All 17 learning events have had at least one entry and are shown. Reports printed early in a simulation run will not include all of the learning events if students have not yet entered them. The absence of a learning event in this report (which was listed in the course description in Recap Report 2) means that the total student time spent in this learning event is equal to 0.

The first four columns are constant-valued descriptors of a learning event. They are repeated each time to provide the user with a context in which the variable-valued descriptors should be seen. There is not sufficient space to repeat all of the relevant information, however; sometimes the user will have to turn back to a recap report to ascertain the value of a relevant learning event constant.

L.E.NO.: Column 1 contains the learning event number.

OBJECTIVE: Column 2 contains the name of the objective associated with this learning event.

EVENT DESCRIPTOR: Column 3. All lines that have "TEST" as their event descriptor will have meaningful numbers in their "IF TEST" columns.

ELIG. CATEGORIES: This has the same meaning as it did in Recap Report 2 (Table 3); it shows the student category numbers eligible to take this learning event. If a particular category number is not shown for a learning event and that category is defined, students in the category not shown skip the learning event.

CUMULATIVE STUDENT ENTRIES: The total number of students who have entered this learning event. This number is incremented by the number of students in the section whenever a section actually starts. Any starts that could occur at this time (report print time) have already occurred Any students waiting for other students to form a section of this learning event are not ready to start, however; nor are students in any section waiting for resources.

CUMULATIVE SECTIONS COMPLETED: The total number of sections of this learning event completed since time 0. Any sections scheduled to complete at this report-print time have been completed and are included in this number.

CUMULATIVE STUDENT SKIPS: The total number of students who have skipped this learning event. Student skips are always made on the basis of the student category eligibility of the learning event (see col. 4 above) and the category of the student. For this reason, if students are not being stratified by ability or background, all learning events of the course will have category 1 eligibility, all students will belong to category 1, and no student will skip any learning event.

AVERAGE NUMBER OF STUDENTS: The average number of students concurrently in this learning event during the course time. It excludes those times when no students were in the learning event. The intuitive meaning is "when there were any students in the learning event, this was the average number of such students." Note that, by itself, this number does not imply the average

Table 8

OUTPUT REPORT 2: STUDENTS AND SECTIONS BY LEARNING EVENT NUMBER

LE. NO.	OBJECTIVE	EVENT DESCRIPTOR	ELIG. CATE-GORIES	CUMULATIVE STU-DENT ENTRIES	CUMULATIVE SEC-TIONS COMPLTD	CUMULATIVE STU-DENT SKIPS	AVG. NO.OF STDTS	AVERAGE TIME PER STUDENT	MAXIMUM SECTION SIZE ACHIEVED	MAXIMUM NO.OF STDTS.	MAXIMUM NO.OF CONCURRENT SECTIONS	(IF TEST) CUMULATIVE FAILS	(IF TEST) CUMULATIVE RECYCLES	CURRENT STU-DENTS	CURRENT SEC-TION
1	CONCEPTS	PRESENTATION	1 2 3 4	25	5	0	4.40	1:46	5	5	1	0	0	3	1
2	CONCEPTS	PRESENTATION	1 2 3 4	24	5	0	4.80	0:30	6	6	1	0	0	0	0
3	CONCEPTS	TEST	1 2 3 4	24	24	0	4.80	0:15	1	6	6	1	3	0	0
4	FLOWCHRT	PRESENTATION	1 2 3 4	20	5	0	4.00	1: 0	5	5	1	0	0	0	0
5	FLOWCHRT	GUID. PRACT.	1 2 3 4	20	20	0	4.00	1: 0	1	5	5	0	0	0	0
6	COMMANDS	PRESENTATION	1 2 3 4	24	5	0	4.80	1: 0	7	7	1	0	0	0	0
7	COMMANDS	TEST	1 2 3 4	24	24	0	4.80	0:15	1	7	7	0	5	0	0
8	CODING	PRESENTATION	1 2 3 4	17	4	0	4.25	1: 0	6	6	1	0	0	0	0
9	CODING	UNGUID.PRACT	1 2 3 4	17	17	0	4.25	3: 0	1	6	6	0	0	0	0
10	CODING	CHK. PRACT.	1 2 3 4	17	17	0	4.25	1: 0	1	6	6	0	0	0	0
11	DEBUG	PRESENTATION	1 2 3 4	32	6	0	5.33	0:30	9	9	1	0	0	0	0
12	DEBUG	UNGUID.PRACT	1 2 3 4	32	23	0	4.81	1:35	1	9	9	0	0	9	9
13	DEBUG	TEST	1 2 3 4	23	23	0	4.60	0:30	1	7	7	0	15	0	0
14	METHODS	PRESENTATION	1 2 3 4	11	3	0	3.67	1: 0	5	5	1	0	0	0	0
15	METHODS	UNGUID.PRACT	1 2 3 4	11	8	0	4.00	2:11	1	5	5	0	0	3	3
16	METHODS	CHK. PRACT.	1 2 3 4	8	5	0	5.00	0:38	1	5	5	0	0	3	3
17	METHODS	TEST	1 2 3 4	5	5	0	5.00	1: 0	1	5	5	2	3	0	0

section size. Only if the maximum number of concurrent sections (Col. 11) happens to be 1 is this average section size. Because some sections might be simultaneous and others overlap only slightly, it is not safe to infer average section size from average number of students concurrently in a learning event.

AVERAGE TIME PER STUDENT: This is the cumulative time integral of number of students in the learning event divided by the number of student entries (see cumulative student entries). For example, if one student spent five hours in this learning event and three students spend two hours each, then the cumulative time integral of students over time = $(1 \times 5) + (3 \times 2) = 11$ hours. Dividing by four (the number of students) gives an average time per student of 2.75, or 2 hours and 45 minutes. This average includes any students currently in the learning event and is therefore somewhat distorted in the low direction when there are students in the learning event.

MAXIMUM SECTION SIZE ACHIEVED: The largest section of this learning event that has been started. There may be a larger section that is waiting for resources and has not been started. Section size is a count of the students in a section.

MAXIMUM NUMBER OF CONCURRENT SECTIONS: This refers, once again, only to running sections. There may have been or may be in the future many more sections of this learning event concurrently in existence but not started.

(IF TEST) CUMULATIVE FAILS: If a learning event has an event descriptor (col. 3) of "TEST," this column shows how many students have completed the test and how many have failed it. Naturally, if the failure policy for the course was that all students would complete this course successfully or if the test was "not failable" (see Recap Report 1), the number of failures would be 0.

(IF TEST) CUMULATIVE RECYCLES: If this learning event has an event descriptor of "TEST" and if any students who have taken the test have been caused to recycle, the count of such recycles is given in this column.

CURRENT STUDENTS: The total number of students who are currently in this learning event (in one or more sections) is given in this column.

CURRENT SECTIONS: The number of sections of this learning event currently underway is given here.

Output Report 3. Student Queues by Learning Event

This report is a record of student waiting time in the course. On the left are shown (one line per learning event) the queues for resources. On the right are shown the queues for other students.

Table 9 is an example of this report. Since all resources were declared to be unlimited, there is no waiting of students for resources, and all resource queues are empty. Because some of the learning events have a minimum section size greater than the number of students to arrive from the preceding learning event, there is some waiting in the Queues for Other Students.

Students never enter the Queue for Resources of a particular learning event unless one or more of the resource types needed to start the learning event are not

Table 9

OUTPUT REPORT 3: STUDENT QUEUES BY LEARNING EVENT

	QUEUES FOR RESOURCES							QUEUES FOR OTHER STUDENTS						
LE	AVERAGE NO.OF STUDENTS	MAX NO.OF STUDENTS	AVERAGE TIME IN QUEUE	$AVERAGE TIME IN QUEUE	CUMU-LATIVE ENTRIES	ZERO TIME ENTRIES	CURRENT STUDENTS	AVERAGE NO.OF STUDENTS	MAX NO.OF STUDENTS	AVERAGE TIME IN QUEUE	$AVERAGE TIME IN QUEUE	CUMU-LATIVE ENTRIES	ZERO TIME ENTRIES	CURRENT STUDENTS
1	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	18	18	0
2	0	0	0: 0	0: 0	0	0	0	1	1	0:52	4:35	16	13	1
3	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	24	24	0
4	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	15	15	0
5	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	20	20	0
6	0	0	0: 0	0: 0	0	0	0	1	2	1:11	3:48	16	11	1
7	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	24	24	0
8	0	0	0: 0	0: 0	0	0	0	0	2	0: 0	0: 0	14	12	2
9	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	17	17	0
10	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	17	17	0
11	0	0	0: 0	0: 0	0	0	0	2	2	0:20	3: 0	18	16	0
12	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	32	32	0
13	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	23	23	0
14	0	0	0: 0	0: 0	0	0	0	1	2	1:20	6: 0	9	7	0
15	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	11	11	0
16	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	8	8	0
17	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	5	5	0

$AVERAGE TIME IN QUEUE = AVERAGE TIME IN QUEUE - ZERO TIME ENTRIES

available in the required quantity. When a student enters this queue (and is counted as an entry) the resource may be released by a completing section and made available to the queued student. If no time elapsed between the times the student(s) entered and left the queue, such students will be counted as zero-time entries. By subtracting these zero-time entries from the cumulative entries, it is possible to determine how many students actually waited in the queue.

Students who want to take a particular learning event always enter its Queue for Other Students. If the minimum section size is one or if they complete the minimum section size by their arrival, then the section is immediately formed. Students never wait for students and resources simultaneously. That is, an incomplete section of students is not allowed to compete for resources with a section that is ready to use the resources. If an incomplete section of students were allowed to compete for resources and perhaps reserve resources before all required students were ready, a deadlock in the allocation of resources might occur as follows:

> Assume two sequential learning events; both require resource AAA of which there is one unit available course-wide. This resource has a capacity of two students and is always dedicated (to a single section). The minimum section size for l.e. 1 is one student. Minimum section size for l.e. 2 is two students.
>
> The first student arrives at l.e. 1 and forms a section immediately and reserves resource AAA; l.e. 1 starts and completes in AVG.TIME.ALLWD. That student then goes to l.e. 2 and needs both another student and resource AAA. If the student reserves the resource while waiting for another student, then a deadlock will occur. A later student will never be able to join the first student because prerequisite l.e.1 cannot be completed until resource AAA is available.

L.E.: The learning event number (col. 1) is common to both sides of this report. The next seven columns are associated with the queues for resources at this learning event, and the following seven columns describe the queues for other students at this learning event. Except for the rules through which students are placed in these queues (described above), like columns on each side are similarly defined.

AVERAGE NUMBER OF STUDENTS: The average number of students in the queue during those times when it was not empty. It is analogous to average number of students in a learning event in the preceding report.

MAXIMUM NUMBER OF STUDENTS: The maximum number of students waiting for resources for use in this learning event at any one time (so far). It might also be described as the maximum length of the queue. This count will not include any students who were zero-time entries.

AVERAGE TIME IN THE QUEUE: Average time spent in the queue by all students who entered the queue, including zero-time students. .

AVERAGE TIME IN THE QUEUE: The time spent waiting by students averaged over only those who actually waited—those with non-zero wait times. The count of such students may be obtained by subtracting zero-time entries (2 cols. to the right) from cumulative entries (one col. to the right).

CUMULATIVE ENTRIES: The total number of students who have entered the queue.

ZERO-TIME ENTRIES: The number of students who entered the queue and remained for zero time.

CURRENT STUDENTS: The number of students who are waiting for resources (or other students, depending on the side of the report) for use in this learning event at this simulated time in the course.

Output Report 4. Resource Utilization by Learning Event

This report gives a detailed history of resource type use at each learning event. Course-wide resource use figures are provided in Output Report 4 (Table 10). However, when a resource type is used in more than one learning event it is sometimes useful to examine the distribution of total use hours over the individual learning events. The first column of this report gives the learning event number. Following this is a line for each resource type used in the learning event. Each resource type line contains a resource number/name pair followed by the capacity of the resource type for purposes of this learning event. (The capacity is a constant repeated here for reference.)

CURRENT NUMBER OF UNITS IN USE: The current number of units of each resource type in use for this learning event at the time of the report. For example, there was one CLSROOM and one INSTR. in use for l.e. 1 at the start of the 30th course hour. There were .8 T.ASST.s in use and .4 CLSROOMs in use for l.e. 10. Fractional numbers of units can occur only when a resource is shareable for a particular learning event.

CURRENT NUMBER OF UNITS RESERVED: The current number of units being held by waiting sections of this learning event (until all remaining resources required by the section are available). As the resources become available they will be added to the number of resources reserved by the section until the reserved amounts are equal to the amounts required. At that time the section will proceed and these resources will be "in use." No units are reserved in this example because there are unlimited resources and no waiting is necessary for resources to become available. In the "unlimited resources" cases resources are added to inventory as they are needed.

CURRENT NUMBER OF UNITS REQUESTED: The number of resources of each type that are not yet available to one or more waiting sections of this learning event. The sum of Current Units Reserved and Current Units Requested is equal to the Units Required by the waiting section(s) in order to start. In this example, there are no requests outstanding for units at any of the learning events (see Table 10).

MAXIMUM IN CONCURRENT USE FOR THIS LEARNING EVENT: This is the maximum number of units of this resource type concurrently in use for this learning event. For example, between time = 0 and time = 30.0 hours, six was the maximum number of units of resource type 5 in use at any single moment of time for learning event 9 (see Table 10).

Table 10

Output Report 4: Resource Utilization by Learning Event

LE NO.	RESOURCE: NO. NAME	CAPACITY (IN STUDENTS)	CURRENT NO. OF UNITS IN USE	RESERVED	REQUESTED	MAX IN CONCURRENT USE FOR THIS LE	CUMULATIVE USE HOURS	CUMULATIVE STUDENT USE HOURS
1	1 INSTR	15	1.000	0.	0.	1.000	10: 0	44: 0
	7 CLSROOM	15	1.000	0.	0.	1.000	10: 0	44: 0
2	1 INSTR	15	0.	0.	0.	1.000	2:30	12: 0
	7 CLSROOM	15	0.	0.	0.	1.000	2:30	12: 0
3	4 TESTER	1	0.	0.	0.	6.000	6: 0	6: 0
	7 CLSROOM	10	0.	0.	0.	.600	0:36	6: 0
	8 MONITOR	10	0.	0.	0.	.600	0:36	6: 0
4	1 INSTR	15	0.	0.	0.	1.000	5: 0	20: 0
	7 CLSROOM	15	0.	0.	0.	1.000	5: 0	20: 0
5	2 T.ASST.	5	0.	0.	0.	1.000	3:60	20: 0
	7 CLSROOM	10	0.	0.	0.	.500	1:60	20: 0
6	3 PROG.TXT	1	0.	0.	0.	7.000	24: 0	24: 0
	6 CARREL	1	0.	0.	0.	7.000	24: 0	24: 0
7	4 TESTER	1	0.	0.	0.	7.000	6: 0	6: 0
	6 CARREL	1	0.	0.	0.	7.000	6: 0	6: 0
8	1 INSTR	15	0.	0.	0.	1.000	4: 0	17: 0
	7 CLSROOM	15	0.	0.	0.	1.000	4: 0	17: 0
9	5 TERMINAL	1	0.	0.	0.	6.000	51: 0	51: 0
10	2 T.ASST.	5	-.000	0.	0.	1.200	3:24	17: 0
	7 CLSROOM	10	0.	0.	0.	.600	1:42	17: 0
11	1 INSTR	15	0.	0.	0.	1.000	3: 0	16: 0
	7 CLSROOM	15	0.	0.	0.	1.000	3: 0	16: 0
12	5 TERMINAL	1	9.000	0.	0.	9.000	50:30	50:30
13	4 TESTER	1	0.	0.	0.	7.000	11:30	11:30
	6 CARREL	1	0.	0.	0.	7.000	11:30	11:30
14	1 INSTR	15	0.	0.	0.	1.000	3: 0	11: 0
	7 CLSROOM	15	0.	0.	0.	1.000	3: 0	11: 0
15	5 TERMINAL	1	3.000	0.	0.	5.000	24: 0	24: 0
16	2 T.ASST.	5	.600	0.	0.	1.000	0:60	5: 0
	7 CLSROOM	10	.300	0.	0.	.500	0:30	5: 0
17	4 TESTER	1	0.	0.	0.	5.000	5: 0	5: 0
	7 CLSROOM	10	0.	0.	0.	.500	0:30	5: 0
	8 MONITOR	10	0.	0.	0.	.500	0:30	5: 0

CUMULATIVE USE HOURS: This is the number of units in use multiplied by the time interval over which they were used, summed for this learning event. If equipment items each had use-meters on them, one use-meter for each learning event where they were used, this number would equal the in-use reading on a particular learning event at this time in the course. The assumptions made are that an item is "in use" only when a section is started and not, for example, when the unit is reserved—even though it is unavailable for other use in both cases. Also, while a section is running, only those portions of a resource unit that are unavailable to other users are considered in use. If a dedicated resource unit that has a capacity of five students is used in a one-hour section containing only two students, it will accumulate one use hour.

If the same resource unit were shareable rather than dedicated, then during an hour when only two students used it, it would be considered only 2/5 (or 40 percent) occupied and would accumulate only 24 minutes of time or 24/60 of a use hour.

CUMULATIVE STUDENT USE HOURS: An extension of the number of use hours of this equipment type (for this learning event) multiplied by the number of students using the unit(s) during each interval. A comparison of these columns will provide a ratio of equipment units to students for each resource type and learning event. For example, varying instructor/student ratios may be examined by looking at these columns for the appropriate resource types.

Output Report 5. Resource Utilization by Resource Type

This report shows resource use for the entire course. It is a summary of the information given in Report 4. In addition, it provides information on the simulation of unlimited resources. Table 11 is an example of this report.

The first two columns give the resource name/number pair. The next column is a repetition of the specification for this resource—whether it was specified in a limited quantity or as unlimited. When the "Qty.Ltd?" column is checked under "No" the model simulates the acquisition of resources as needed. The acquisition is instantaneous. The idea is not to simulate acquisition as such but to simulate student demand for a given course design in order to estimate required resources from the simulation-generated requirement. If a resource type with unlimited quantity is always dedicated, the total number of units currently in the system should equal the maximum number of units concurrently in use. A unit of the resource type is added to the system only when it is needed and about to be used. If, however, the planner uses unlimited resources in conjunction with severely limited resources, a false projection of the need for this resource can occur. See Sec. IV for a discussion of this problem. If this resource type is sometimes or always shareable, the maximum number of units concurrently in use may be a little less than the total number of units currently in the system because additional units are added to the system only in integral units and with shareable resources the requirement causing such an addition might be fractional.

TOTAL NO. OF UNITS CURRENTLY IN SYSTEM: If the quantity-limited column shows an X under "yes" then this number is a repetition of the limited quantity specified in Recap Report 3 (Table 4). For unlimited quantity resources, this

Table 11

Output Report 5: Resource Utilization by Resource Type

RESOURCE NO.	NAME	QTY.LTD? YES/NO	TOTAL NO. OF UNITS CURRENTLY IN SYSTEM	IN USE	RESERVED	REQUESTED	MAXIMUM NO.OF UNITS CONCURRENTLY IN USE	TOTAL ACTUAL USE HOURS	TOTAL UNIT-HOURS	AVERAGE PER CENT UNIT-HOURS FULLY IDLE
1	INSTR	X	3.00	1.00	0.	0.	3.000	27:30	90: 0	69.44
2	T.ASST.	X	3.00	.60	0.	0.	2.000	8:24	90: 0	72.50
3	PROG.TXT	X	7.00	0.	0.	0.	7.000	24: 0	210: 0	88.57
4	TESTER	X	9.00	0.	0.	0.	9.000	28:30	270: 0	89.44
5	TERMINAL	X	17.00	12.00	0.	0.	17.000	125:30	510: 0	75.39
6	CARREL	X	9.00	0.	0.	0.	9.000	41:30	270: 0	84.63
7	CLSROOM	X	3.00	1.30	0.	0.	3.000	32:48	90: 0	57.22
8	MONITOR	X	1.00	0.	0.	0.	.600	1: 6	30: 0	92.50

is the number of units required by the course so far. If a resource is specified as an unlimited quantity resource and it is not used in conjunction with any other limited quantity resource, then total NO. OF UNITS CURRENTLY IN SYSTEM is equal to the MAXIMUM CONCURRENTLY IN USE (column 8) rounded up to the nearest integer.

TOTAL NO. OF UNITS CURRENTLY IN USE: The total number of units of this resource type now in use by any and all sections in the course.

TOTAL NO. OF UNITS CURRENTLY RESERVED: The number of units currently reserved by any and all sections of learning events. Note that a reservation of a resource shown in this report means that either not enough units of this resource are available to start the section or units of some other resource type (that are used with this resource type) are unavailable.

TOTAL NO. OF UNITS CURRENTLY REQUESTED: The number of units of each type that would at this time allow all resource-queued sections to be dequeued and start. The resource quantities reserved (preceding column) plus those requested plus those in use are the total resources required by all students in the system at this time. This column shows the unavailable portion of that requirement.

When a combination of limited and unlimited resource types have been used, particularly in the same learning event, the highest number of resource units acquired (for the unlimited types) will not be a valid indicator of the number of such units needed to prevent delays. It is likely to be too high.

> Suppose learning event 1 requires one unit of resource A, which is limited, and one unit of resource B, which has been specified unlimited. Every section that is unable to acquire a unit of resource A will request it and queue up for it. The section will also request and reserve, if possible, any other resources needed. One unit of resource B is needed so it is requested; this causes it to be created or "acquired" and then it is reserved. As more sections queue up for resource A, additional units of resource B are requested, acquired, and reserved. If resource A is required for a full hour and is requested every half hour and if the supply is limited to one unit then the queue length will increase without bound over time. Similarly the number of units of resource B that are acquired will also continue to increase over time. Yet it is clear that under the above conditions only one additional unit of resource A would remove the queueing requirement. Mixed specifications lead to misleading indicators and the user should not use them. Either all resources should be considered unlimited or all should have quantities specified for them.

MAXIMUM NO. OF UNITS CONCURRENTLY IN USE: Defined as concurrent use regardless of learning event. It is the maximum number of units that have been concurrently in use throughout the course.

TOTAL ACTUAL USE HOURS: The sum of the cumulative use hours by resource type across learning events. See "Cumulative Use Hours" in Output Report 4. For example, in Table 11 total actual use hours for the classroom are 32

hours and 48 minutes. Table 10 gives the cumulative use hours for classroom as:

10 hrs,
2 hrs, 36 mins.,
36 mins.,
5 hrs,
2 hrs,
4 hrs,
1 hr, 42 mins.,
3 hrs,
3 hrs,
30 mins., and
30 mins.

for a total of 32 hrs, 48 mins.

TOTAL UNIT-HOURS: Number of units of this type in the system multiplied by the number of hours simulated (the time of this report). Represents total available resource hours.

AVERAGE PERCENT UNIT-HOURS FULLY IDLE: Computed by dividing the time integral of Number of Units Fully Idle by the total unit-hours (above) for that resource type. The time integral of Number of Units Fully Idle is simply the cumulative sum of fully idle hours of all units of this resource. The distinction between idle and fully idle is made because resources may be partly idle if they are shareable; or they may be in use but not to full capacity when they are dedicated.

Output Report 6. Sections Queued by Resource Type

This report gives more information on resource wait queues, which are seen as section rather than student queues and are associated with a resource type rather than a learning event. (See Table 12.) When resources are requested they are requested by a section (of one or more students) that will be prepared to start immediately when all the required resources are available. The section is queued for the resource and, in addition, the students in the section are enqueued at the learning event so that interactions between overall resource demand and demand generated by certain parts of the course may be examined. This report has one line representing the section queues for each resource type. The same section may be queued for more than one resource type and would thus appear more than once in this report.

RESOURCE TYPE: The number of the resource type.

AVERAGE NUMBER OF SECTIONS: The average number of sections waiting for resources of this type.

MAXIMUM NUMBER OF SECTIONS: The maximum number of sections concurrently waiting for resources of this type. If a section is waiting for more than one type of resource it will appear in more than one section queue.

AVERAGE TIME IN QUEUE: The average amount of time that any section spent in the queue.

AVERAGE TIME IN QUEUE: The average amount of time spent in the queue by sections that did not pass through the queue in zero time.

CUMULATIVE SECTIONS: The total number of section entries into this queue.

ZERO TIME SECTIONS: The total number of entries into this queue that passed through it in zero time. The total number of sections that spent non-zero time in the queue is obtained by subtracting zero-time sections from cumulative sections.

CURRENT SECTIONS QUEUED: The current number of sections queued for resources of this type. They might be from one learning event or many. This report provides only the total number of sections queued.

Table 12 is not very interesting because there are no resource queues of any kind generated in an unlimited resource case.

Table 12

OUTPUT REPORT 6: SECTIONS QUEUED BY RESOURCE TYPE

RESOURCE TYPE	AVERAGE NO.OF SECTIONS	MAXIMUM NO.OF SECTIONS	AVERAGE TIME IN QUEUE	$AVERAGE TIME IN QUEUE	CUMU-LATIVE SECTIONS	ZERO TIME SECTIONS	CURRENT SECTIONS QUEUED
1	0	0	0: 0	0: 0	0	0	0
2	0	0	0: 0	0: 0	0	0	0
3	0	0	0: 0	0: 0	0	0	0
4	0	0	0: 0	0: 0	0	0	0
5	0	0	0: 0	0: 0	0	0	0
6	0	0	0: 0	0: 0	0	0	0
7	0	0	0: 0	0: 0	0	0	0
8	0	0	0: 0	0: 0	0	0	0

$AVERAGE TIME IN QUEUE = AVERAGE TIME IN QUEUE - ZERO TIME SECTIONS

IV. THE SAMPLE CASE

Appendix B presents the Resource Utilization Model output for the sample case.[1] Included in the output is the summary of initial conditions—the series of initial reports that reflect the inputs and thus document the particular course design parameters being simulated. By following the definitions of output variables as given in Sec. III, the reader may interpret the results of the simulation of the sample case design.

This section will touch very briefly on a few of the less obvious elements of the sample case output. It is meant to be read while examining the reports (both summary input and output) in App. B.

As seen in App. B, reports are requested every 768 hours and the simulation is scheduled to end at 768 hours. Earlier runs of the case with much more frequent report intervals had been examined and analyzed before this final run was made. The output reports are in no sense a set of "answers" that may be evaluated at a single point in time. Rather, they are windows into the events in a time stream and can best be understood through an examination of the trends and interactions of the indicators that have been selected for reporting. The examination of a set of reports for a single point can be misleading; that point may coincide with the high or low in a cyclical trend, leading the planner to miss otherwise obvious course interactions or side-effects. Studying the reports and their relationship to each other and to the underlying pattern of student arrivals can be a complex task. However, it is the only way to gain the insights into the course dynamics that the model provides.

Part 1 of the Summary of Initial Conditions in App. B shows that the sample case has a fixed number of students (8), arriving at fixed time intervals (30 hours). The students belong to one of four categories, and upon arrival at the course each student's category is determined and that student is assigned category numbers. The determination is made by a random number draw so that the cumulative proportion of students in each category will reflect that defined in the input specifications. This is analogous to deciding in advance the expected representation of the characteristic Electrical Engineering Training (E.E.Tng.) in the arriving population (12 percent + 18 percent = 30 percent). In addition, it is assumed that on the average (and regardless of E.E.Tng.) 40 percent of the students will be classifiable as "slow" and 60 percent as "fast." However, each arrival group is not expected to be a representation of these percentages, which are only for the population as a whole, and each group is composed of students selected randomly from that population. In the group of students arriving at each time, one or more of the categories may not be represented at all or may be represented very strongly. This is an important design consideration and affects the flow of students through any course that discriminates by ability or characteristic and requires a minimum number of students greater than one in any learning event that so discriminates. Both of these conditions are met in the sample case; this point will be further elaborated upon below.

[1] This sample case was first presented and developed more fully in the MODIA reports R-1700 and R-1702.

The student grouping policy selected by the planner is also shown in App. B. Note here the categories into which students are divided. "Resource Utilization Model, Course to be Simulated," shows course specification and the categories of students that are eligible for each learning event in the course. Each of the students in the four categories is to be taught in one of three ways. (The treatment for two of the categories is very similar.) Those students with the prescribed background characteristic E.E.Tng., whether slow or fast students (categories 2 and 4), are presented the same material (l.e.s 58-84) and spend equal time on it. The only exception to this is an initial presentation and homework assignment (l.e. 58-59) and a later review (l.e. 81), which the category 4 students (fast students with E.E.Tng.) are allowed to skip. Skipping l.e. 58 puts all category 4 students from a particular arrival group 45 minutes ahead of category 2 students in that same group until graduation, unless a lack of resources slows down the faster starters sufficiently that those not skipping the first event catch up. This may be important to consider if some pairing of slow and fast students was envisioned. For example, category 4 students are expected to be represented by only 18 percent of the population; and in an arrival group of eight this representation will probably mean only one or two students, sometimes none, and sometimes more. When there is only one such student in category 4 (and assuming no resource constraints), that student will start with learning event 60 and proceed freely until learning event 64, at which time there will be a wait for any category 2 or category 4 student. Category 2 students represent an even smaller proportion of the student population (12 percent) and must also take learning event 64 with at least one other student. If two category 4 students should be in the same arrival group they will not need to wait for a category 2 student at learning event 64. Therefore, category 2 students would occasionally have to wait for a student from the next arrival group. "Student Queues by Learning Event—Queues for Other Students" indicates that 15 students waited for other students an average of 18 hours and 9 minutes each at this learning event. Many and maybe most of these students were from category 2.

Students without E.E.Tng., whether fast or slow (categories 1 and 3), are to be treated differently from each other and from the first two groups mentioned. These differences in treatment cannot be inferred from these reports except that they each take a different series of learning events. The differences in treatment, however, are specified in the summaries of interaction provided the planner by the User Interface.

"Course to be Simulated" shows that in the sample case all learning event times are fixed. That is, the maximum time allowed is equal to the average time allowed is equal to the minimum time allowed. There are occasionally a minimum number of students greater than one required for particular learning events in each "track".[2] Note also the 15 percent failure rate and the distribution of those failures across student categories. Category 2 and 4 students (see "Summary of Initial Conditions"), who receive essentially the same material, have different failure rates. The failure rate for category 2 students ("slow" students with E.E.Tng.) is three times as high as that for category 4 students ("fast" students with E.E.Tng.). These category 2 and 4 students will be taking the same test (learning event 84) but will fail the test at different rates. Also note that the slow students with E.E.Tng.

[2] In this case "track" is being loosely used to mean any one of the three nonintersecting sets of learning events mentioned above.

are expected to fail the course at a higher rate than are slow students without E.E.Tng. That is, for every 28 students for category 1, on the average 7-1/2 will fail this course (50 percent of 15 percent). However, for every 12 students from category 2, on the average 4-1/2 will fail (30 percent of 15 percent). Thus any given category 2 student is more likely to fail than a category 1 student.

"Course to be Simulated" indicates the eligibility categories, student requirements, time allowed, recycle points, etc. These reports are followed by resource requirements and resource definitions and specification tables.

The first output report (as distinguished from the recap or input reports) at time 768 course hours shows the simulated number of student arrivals, failures, and graduations in summary. Peak student load (13) differs from average student load (8.3) and reflects in part the students delayed waiting for other students and also students recycling through the course. The average time to finish the course should be very close for students from categories 2 and 4 since they cover essentially the same material, give or take one or two hours. Therefore, since the average time to finish is so different for group 2 (52:31) and group 4 students (26:51), it may be worthwhile to look for an explanation. Part of this additional time to finish the course was discussed above (arrival group sizes and minimum students required for learning event 64). At best, however, that could account for only an extra 18 hours per category 2 student and there is an almost 26-hour difference (on the average). "Student Queues by Learning Event" shows that five students waited an average of 59 hours and 3 minutes each for another student in order to take learning event 81, which is restricted to category 2 students. This amounts to a total additional wait time of 295 hours for category 2 students or about 19 extra hours per student (15 graduated) in addition to any waiting explained by the requirements and queues at learning event 64. The wait at l.e. 81 is occasioned by the fact that a category 2 and a category 1 student may have been traveling through the course together from l.e. 64 only to have the category 2 student lose his required "partner" at l.e. 81, which must be skipped by category 4 students. The unlucky student then waits for the next arrival group to get to almost the end of the course to join him.

There are analogous waits in the other tracks in the course. For example, learning event 38, in the series of learning events restricted to category 3 students, is the first in that series to require a minimum of two students rather than one ("Student Queues by Learning Event"). Six students waited an average of 16 hours each for a student from the next arrival group or from a recycle at this learning event.

Resource competition among the different learning events can occur among learning events in the same track as well as in different tracks. For example, in learning events 9, 14, and 16, students are forced to wait for resources. For most group 1 students, learning event 9 starts at the tenth course hour ("Students and Section by Learning Event Number"). L.e. 9 uses resources 5, 10, and 14 (see "Resources Required by Learning Event"). Because both the other tracks have several waits early in their series (for both students and resources), it is not possible to pinpoint from these reports exactly which learning events are using these resources at that time. Only more frequent reporting could shed light on these types of interactions. The cross-reference table of "Learning Events by Resource Type" shows that of the 17 resources defined for the course, 11 of them will be used by

students in all three tracks. Since the tracks are run concurrently (except for occasional recycles) there should be a good sprinkling of concurrent demand for these resources as is reflected in "Resource Utilization by Learning Event," by learning event, and in "Sections Queued by Resource Type."

There are waits by student (for other students) at learning events 14 and 16, which may not be immediately obvious unless the reader has grasped formation of sections and the competition for resources (see Sec. II, p. 14 for a more general discussion). Learning event 14 is not the first learning event in the track for category 1 students that requires more than one student. In fact, "Course to be Simulated" shows nine learning events in this track preceding learning event 14 with a requirement of at least two students. However, learning event 14 does have a record of resource competition. This means that there were at least two separate occasions at learning event 14 when a number of students were ready to enter the learning event only to find that there were not enough resources for all of them. According to model rules, if there were enough resources for some number of them greater than or equal to the minimum required, the section would be formed and commence immediately, leaving any not accommodated for the next section. If there were two or more stragglers they could start a new section and queue up for resources. (Those who did so are shown on the left side of "Student Queues by Learning Event.") If there were not at least two left behind, the student left would have to wait for another student to come along to form a section (probably occurring only after the next arrival group or upon a recycle). When fragmentation of this sort is caused or contributed to by lack of resources, an increase in available resources will eliminate or alleviate the problem.

V. INPUT SPECIFICATIONS

This section shows how the User Interface passes a course design to the Resource Utilization Model. Since these specifications drive the system design they may prove useful to the reader who is also a user. For each variable that may be passed from the User Interface to the Resource Utilization Model there is an entry consisting of a variable name, the mode of the variable, the allowable range of values for numeric variables (or the size for alphanumeric variables), and a definition. If the variable values are interpreted as codes, the code definitions are given. Variables are presented in the order in which the model reads them.

The formats in which the model expects all of these variables are described and shed some light on the "mode" of the variables. This material is not intended for the ordinary user of MODIA but is essential to anyone who might want to make minor modifications to the system. It is also an important part of the system documentation.

THE COURSE

Variable Name: SARO
Mode: Integer
Allowable Range: $1 \leq N \leq 4$
Definition: Student Arrival Rule Option takes a value of 1, 2, 3, or 4 depending on the arrival rule selected:

1. Students arrive in groups of a fixed size and at fixed time intervals. Example: Every 30 course hours ten students arrive at the course.

2. Students arrive in groups whose size is determined randomly about a given mean and at random time intervals around another mean. Example: About ten students arrive approximately every 45 course hours.

3. Students arrive in groups whose size is determined randomly (drawn from a normal distribution with a mean of ARR.GRP.SZ and a standard deviation = 1/3 of ARR.G.DEV below) but the time between arrivals is fixed. Example: ten to 20 students arrive every 40 course hours.

4. Students arrive in groups of a fixed size but the time between arrivals of these groups is random (drawn from a normal distribution with mean = INTER.ARR.TIME and SD = IAT.DEV/3). Example: Exactly 20 students arrive about every 40 course hours.

Variable Name: ARR.GRP.SZ
Mode: Integer
Allowable Range: $N > 0$

Definition: The number of students in an arriving group of students at the course. If a random group size was specified above, this will be interpreted as the mean group size.

Variable Name: INTER.ARR.TIME
Mode: Integer
Allowable Range: N > 0
Definition: The number of hours between arrivals. If a random inter-arrival time was specified, this will be interpreted as the mean inter-arrival time.

Variable Name: ARR.G.DEV
Mode: Integer
Allowable Range: N > 0
Definition: This item is required only if SARO = 3. Deviation from mean arrival group size. This should be equivalent to three standard deviations so that ARR.GRP.SZ + ARR.G.DEV will encompass 99 percent of group size range.

Variable Name: IAT.DEV
Mode: Integer
Allowable Range: N > 0
Definition: This data item is required only if SARO = 4. Deviation from mean inter-arrival time in hours. Should also be equivalent to three standard deviations so that INTER.ARR.TIME + IAT.DEV will encompass 99 percent of group size range.

Variable Name: REPORT.INTERVAL (in hours)
Mode: Real
Allowable Range: N > 0
Definition: The number of course hours between R.U.M. reports.

Variable Name: SIM.END.OPT
Mode: Integer
Allowable Range: 0 or 1
Definition: 0. Run R.U.M. for a specified number of simulated course hours.

1. Run R.U.M. until a specified number of students graduate from the course.

Variable Name: ENDVAR (Hours or Students)
Mode: Real
Allowable Range: N > 0
Definition: This is either the specified number of course hours or the specified number of graduates which will determine R.U.M. run time. See SIM.END.OPT above.

Variable Name: ADAPT.POL
Mode: Integer
Allowable Range: $0 \leq N \leq 5$

Definition: 0. Students will not be stratified by ability or background at any time in the course. No. categories = 1.

1. Students will be stratified by background only. No. categories = 2.

2. Students will be stratified by ability only into two categories.

3. Students will be stratified by ability only into three categories.

4. Students will be stratified by ability only into four categories.

5. Students will be stratified by ability (into two categories) and independently of ability by background for a total of four categories.

Variable Name: BGNAME
Mode: Alpha
Allowable Range: $5 \leq$ LENGTH ≤ 8 CHARS.
Definition: The name of the background characteristic. This data item should be supplied only when ADAPT.POL was specified as 1 or 5—i.e., background stratification is being used. For example, in the sample case given in App. B, BGNAME was "E.E.TNG."

Variable Name: BG.PERC
Mode: Real
Allowable Range: $0 < N < 1.0$
Definition: The fraction of students with the background characteristic. Do not supply unless ADAPT.POL = 1 or 5.

Variable Name: UPPR.ABIL
Definition: An array of three values, each of which may specify an upper cutoff for an ability group. They are listed separately below as their ranges differ.

Variable Name: UPPR.ABIL(1)
Mode: Real
Allowable Range: $0 < N < 1.0$
Definition: The fraction of students in the slowest ability category. Specify only if ADAPT.POL = 1.

Variable Name: UPPR.ABIL(2)
Mode: Real
Allowable Range: UPPR.ABIL(1) $< N < 1.0$
Definition: The fraction of students in the bottom two ability categories. Specify only if ADAPT.POL = 3 or ADAPT.POL = 4.

Variable Name: UPPR.ABIL(3)
Mode: Real
Allowable Range: UPPR.ABIL(2) $< N < 1.0$
Definition: The fraction of students in the bottom three ability categories. Specify only if ADAPT.POL = 4.

Variable Name:	FAILRATE
Mode:	Real
Allowable Range:	$0 \leq N < 1.0$
Definition:	The total fraction of students who will fail the course.

Variable Name:	PC.FAIL.GRP(1), PC.FAIL.GRP(2), PC.FAIL.GRP(3), PC.FAIL.GRP(4).
Mode:	Real
Allowable Range:	$0 \leq N \leq 1.0$
Definition:	Specify only if both ADAPT.POL and FAILRATE are greater than zero. PC.FAIL.GRP(1) is the fraction of failures who will be from category 1. As many data items must be provided as there are categories for the ADAPT.POL chosen. (The table below shows the number of categories by ADAPT.POL value and the definition of each category.) The fractions provided must sum to 1.0 but the fraction of all but one category may be zero. For example, when ADAPT.POL = 2 (and failrate > 0) there are two categories of students (see column 2 below): Category 1 refers to the slow students and category 2 refers to the fast students. When ADAPT.POL = 3, there are three categories, and category 2 refers to the average students.

ADAPT. PL:	NO. OF CATEGORIES	CATEGORY NUMBERS: 1	2	3	4
0	1	ALL			
1	2	W/O	W		
2	2	S	F		
3	3	S	A	F	
4	4	S	S′	F′	S
5	4	SW/O	SW	FW/O	FW

NOTE: W/O means students without the special characteristic; W students with the special characteristic; F or S before these indicates fast or slow students. A means average, S′ means faster slow, and F′ slower fast.

Variable Name:	N.OBJ
Mode:	Integer
Allowable Range:	$N > 0$
Definition:	The number of objectives in the course.

Variable Name:	OBJ.NAME(I), I = 1 to N.OBJ
Mode:	Alpha
Allowable Range:	LENGTH = N CHARS, $5 \leq N \leq 8$
Definition:	The name of the Ith objective to be used for reports only.

Variable Name:	N.LE.DESCRIPTOR
Mode:	Integer
Allowable Range:	$N > 0$
Definition:	The total number of learning events in the course.

For each learning event, the following variables must be provided:

Variable Name: LENUMBER
Mode: Integer
Allowable Range: $1 \leq N \leq$ N.LE.DESCRIPTOR
Definition: The identification number of the learning event. These numbers must be sequential integers from 1 to N.LE.DESCRIPTOR.

Variable Name: Objective Sequence number
Mode: Integer
Allowable Range: $1 \leq N \leq$ N.OBJ
Definition: The sequence number of the objective associated with this learning event.

Variable Name: SUBJ.MATTER.TYPE
Mode Integer
Allowable Range: $1 \leq N \leq 10$
Definition: A code defining subject matter types for report purposes.[1]

1. Easy facts and concepts
2. Difficult facts and concepts
3. Simple classroom skills with selected response
4. Simple classroom skills with constructed response
5. Complex classroom skills with selected response
6. Complex classroom skills with constructed response
7. Team skills with special equipment
8. Individual product skills with special equipment
9. Individual process skills with special equipment
10. Individual product and process skills with special equipment

Variable Name: EVENT.DESCR
Mode: Alpha
Allowable Range: LENGTH = 2
Definition: P. = Presentation; GP = Guided Practice; IP = Unguided Practice; D. = Discussion; CP = Check Practice; H. = Homework; R. = Review; T. = Test; NOTE: The "T." code is used by the R.U.M. to differentiate between regular learning events and exams. If "H." is the subject matter type of a learning event, the average time allowed must be 0.0 and no resources may be required.

Variable Name: AVG.TIME.ALLWD (In Minutes)
Mode: Real
Allowable Range: $0 \leq N$

[1] These types are defined and discussed in R-1702-AF, *Operation and Design of the User Interface*.

Definition: The completion time for one section of this learning event. If a student is progressing individually (MAX.STUDENTS.ALLWD = 1), the student's ability will be used to modify this time within the MIN.TIME.MULT and the MAX.-TIME.MULT constraints.

Variable Name: FLOW.CODE
Mode: Integer
Allowable Range: $1 \leq N \leq 15$
Definition: A FLOW.CODE is associated with each learning event and indicates (as shown in the table below) the categories of students that are eligible for the learning event. See PC.FAIL.GRP above for definition of categories. The number of categories depends on ADAPT.POL. Category numbers always start with 1, so that for ADAPT.POL = 0, FLOW.-CODE must always be 1. For example, a flow code of 7 could be used if ADAPT.POL were 3 or greater and it would mean that category 1, 2, and 3 students were eligible for a learning event. This would then be used by the model and shown in the reports.

FLOW. CODE	CATEG.1	CATEG.2	CATEG.3	CATEG.4
1	X			
2		X		
3	X	X		
4			X	
5	X		X	
6		X	X	
7	X	X	X	
8				X
9	X			X
10		X		X
11	X	X		X
12			X	X
13	X		X	X
14		X	X	X
15	X	X	X	X

Variable Name: MAX.STUDENTS.ALLWD
Mode: Integer
Allowable Range: $0 <$ MIN.NO.STUDENT.REQD $\leq N$
Definition: The maximum number of students to be allowed in one section of this event. (A section is defined as a separate occurrence of the learning event. Once a section begins, students may not join or leave until the section finishes. A section is created whenever the MIN.NO.STUDENTS.REQD are eligible to take the learning event. The section then waits for resources and begins when they are available. New students up to the MAX.STUDENTS.ALLWD may enter an existing section any time before it begins as long as any additional resources required can be obtained without violating the

first-come-first-served rule. Additional sections are created as needed. There is no limit to the number of concurrent sections for a learning event.)

Variable Name:	MIN.NO.STUDENTS.REQD
Mode:	Integer
Allowable Range:	$N > 0$
Definition:	The minimum number of students required to start one section of this learning event.

Variable Name:	MAX.TIME.MULT
Mode:	Real
Allowable Range:	$N \geq 1.0$
Definition:	When students are progressing at individual rates according to their abilities, this factor will be multiplied by AVG.TIME.ALLWD and will provide the upper limit to be allowed regardless of student ability.

Variable Name:	MIN.TIME.MULT
Mode:	Real
Allowable Range:	$N \leq 1.0$
Definition:	Same as MAX.TIME.MULT but provides the lower bound on time.

The following are provided for a learning event only if it has an EVENT.DESCR (see above) of "T.".

Variable Name:	P.FAILS
Mode:	Integer
Allowable Range:	0 or 1
Definition:	P.FAILS is the possibility of failure at this test. 0 = no students will fail. 1 = some students will fail. Where more than one learning event has a P.FAILS = 1, failures will be distributed in equal proportions across such tests.

Variable Name:	PC.RECYCLE
Mode:	REAL
Allowable Range:	$0 \leq N \leq 1.0$
Definition:	The fraction of passing students who should recycle back from this test. Specify only if EVENT.DESCR = "T.".

Variable Name:	LEREC
Mode:	Integer
Allowable Range:	LEREC may be any learning event number ≤ LENUMBER of the test.
Definition:	The learning event number to which students must recycle. Specify only if PC.RECYCLE > 0.

Variable Name:	MAX.NO.RECYCLES
Mode:	Integer
Allowable Range:	$1 \leq N$
Definition:	The maximum number of times that a particular student is eligible for recycle from this test. Specify only if PC.RECYCLE > 0.

THE RESOURCES

Only non-consumable resources are to be considered in the Resource Utilization Model. Resource types should be aggregated as much as possible for model efficiency and to facilitate output assimilation. They may be characterized by quantity, capacity, and shareability. Quantity means the number of units of this resource type available for course use during class hours. The user may specify a limited quantity or may request an unlimited quantity.

Resource capacity is defined in terms of the number of students who can be accommodated by one unit of this resource type. It may be undefined or defined. If it is to be defined, it may be specified as fixed over the entire course or it may vary and must then be specified by learning event. Undefined capacity may be specified only for a resource type over the entire course. When the capacity is undefined, the model sets it to one student per unit. When capacity is undefined, quantity should be specified as unlimited.

A resource type may be considered shareable or dedicated. This may be specified at the course level or at the learning event level, i.e., a resource's shareability may be the same for all purposes in the course (either shareable or dedicated) or it may vary by learning event and be shareable for some purposes and dedicated for others. When a resource type is dedicated, integral resource units will be allocated to a learning event section based on the size of the learning event and the capacity of the unit. Any unused capacity will be considered unavailable to other learning event sections until released by the using section. When a resource type is shareable, any unused capacity on a unit is available for concurrent use by students *in other learning* event sections, if the resource type has been specified as shareable for the "other" sections also. Note that shareability and capacity of resources (except for unlimited capacity) can be specified at the course level or at the learning event level.

Variable Name:	N.RSOURCE.TYPE
Mode:	Integer
Allowable Range:	$N > 0$
Definition:	The number of resource types to be used.

For each resource type, the following variables must be provided.

Variable Name:	TYPE.ID.NO
Mode:	Integer
Allowable Range:	$1 \leq N \leq$ N.RSOURCE.TYPE
Definition:	The sequential integer identification number of the resource.
Variable Name:	NAME
Mode:	Alpha
Allowable Range:	$5 \leq N \leq 8$, N=LENGTH IN CHARS.
Definition:	An alphabetic name to be associated with TYPE.ID.NO for output purposes.
Variable Name:	CAP.CODE
Mode:	Integer
Allowable Range:	$-1 \leq N$

Definition: -1 = Undefined capacity 0 = Varying capacity, to be provided by L.E. See NVC below.

$N > 0$; N is the capacity—i.e., the number of students one unit can accommodate.

Variable Name: QTY.CODE
Mode: Integer
Allowable Range: $0 \leq N$
Definition: 0 = Quantity is unlimited. This must be the value of QTY.CODE if capacity is undefined (CAP.CODE = -1.) $N > 0$ = N is the limited quantity available.

Variable Name: SHR.CODE
Mode: Integer
Allowable Range: $1 \leq N \leq 3$
Definition: 1. Dedicated over all course. 2. Shared over all course 3. Dedicated and shared, code to be provided by learning event. See NVS.

If any resource type had a value of zero for CAP.CODE the variables below must follow:

Variable Name: NVAR.CAPS
Mode: Integer
Allowable Range: $N > 0$
Definition: The resource types with a varying capacity—i.e., the types that had a value of zero for CAP.CODES.

Variable Name: NVC
Mode: Integer
Allowable Range: $0 < N$
Definition: An array of dimensions N.LE.DESCRIPTOR by NVAR.CAPS whose values give the capacity of each variable capacity resource type by learning event. There must be one row (of NVAR.CAPS positive integers) for every learning event in the course. The rows must be in sequential order by ascending learning event number. There must be one column (of N.LE.DESCRIPTOR postive integers) for every variable capacity resource type. Columns should be in sequential order with resource type number values ascending from left to right.

If any resource type had a value of three for SHR.CODE the variables below must follow:

Variable Name: NVAR.SHR
Mode: Integer
Allowable Range: $N > 0$
Definition: The resource types that have a variable sharing policy (SHR.CODE = 3).

Variable Name: NVS
Mode: Integer
Allowable Range: 1 or 2
Definition: An array of dimensions N.LE.DESCRIPTOR by NVAR.SHR whose values are the share code 1 or 2 (see SHR.CODE) for each resource type with a variable sharing policy by learning event. There must be one row (of NVAR.SHR values) for each learning event in the course. There must be one column (of N.LE.DESCRIPTOR values) for each resource type with a variable sharing policy. As in array NVC, rows must be in ascending sequential order by learning event and columns must be sequentially ordered by resource type number with that value increasing from left to right.

Variable Name: RESRC.REQMT.TABL
Mode: Integer
Allowable Range: $0 \leq N \leq 1$
Definition: An array NLE.DESCRIPTOR by N.RSOURCE.TYPE must now be provided and a value of 0 or 1 input to indicate whether each resource is used for each learning event.

FORMAT REQUIREMENTS

Data items specified above must appear in the input stream in the exact order specified. Blanks act as delimiters to the data items. That is, at least one blank must precede each data item unless that item is the first on a physical input record, and at least one blank must follow each data item unless it is the last on a physical input record.

Mode of each data item is specified below. Three modes are used:

INTEGER— A non-fractional number, must be represented without a decimal point; e.g., 1, 33, −132.

REAL— A fractional or non-fractional number, may be represented with or without a decimal point; e.g., 1.0, −12.5, 1001.913, 52, 53.

ALPHA— Any combination of letters (A-Z), Digits (0-9), or special characters. The length allowed is specified (in characters) above for each data item. Blanks are not acceptable as part of the ALPHA variable and should be replaced by a period (.); e.g., for length = 4: LAB, RM#1, RM.2, INST; e.g., for length = 8: HOME.RMS (Not: HOME RMS)

VI. MODEL LIMITATIONS AND ASSUMPTIONS

The Resource Utilization Model suffers from certain limitations, some of which are the results of basic model assumptions and cannot be removed without redesign. Others are simply extensions for which budget and time were never found. If this model is used as a basis for reprogramming, this list is a minimal starting set of improvements.

Statistical accumulation of run results is not provided, and there is no way to vary the random number starting seeds so that a single case can be repeated with no variations except for those in the randomly generated events. This is an easy extension.

There is no way of entirely eliminating the startup effects of a course from the averages later provided in reports. Since there is also no way to start with a "full" course, startup effects will always be present. This may be an important consideration for some course simulations. Further feedback from the testing and review sessions conducted by the Air Force at Keesler Air Force Base will determine whether this is a minus.

There are no statistical distributions provided of the output measures; maximums, minimums, and averages are reported. This is a serious flaw and requires more frequent report periods to understand simulation results. This extension was obviously desirable but was not carried out because of development tradeoffs and time limitations.

Selected output reports cannot be suppressed. For example, in the simulation of a course with no limitation on resources there is no way to suppress the report, "Sections Queued By Resource Type." This would actually be fairly easy to do, but because suppression of output reports can cause a user to misinterpret results, it might be best to postpone this capability.

There is no way to get output reports printed at uneven intervals or at special times. Reports are at present printed at time 0, at even time intervals, and at the end of the simulation. This is an option offered automatically in some simulation languages but would have had to be provided in the model in Simscript II.5. Because there was no indication of how useful a feature it would be, it was not added, but it should be considered when there is more experience in the use of the model.

The simulation of resource assignment and resource release are genenerralized, and a particular resource unit (e.g., one 20-student classroom) is not kept track of per se. For shared resources, students are assumed to be reassignable to different units during a learning event or to be able to have fractions of more than one unit assigned for their use. With dedicated resources (where the students must be given integral units of resources), if the units are being released piecemeal by sharing students in another learning event, the accumulation of the required sums of fractions will signal the availability of the integral units for dedicated use. Again, the sharing students are assumed to be reassignable, if necessary, to units that are wholly rather than partially shared. There is nothing wrong with these assumptions for most cases, but no uninterruptable shared resources can be simulated accurately under this scheme. If a course revolves around very expensive equip-

ment items with this characteristic, the limitation could be serious. Changing this in the model would involve modelling resources and their management at a much finer level of detail. The seriousness of this limitation must be judged in the context of real course inputs before such a change is considered.

The simulation of the allocation of sets of resource units of different types depends in this model on a reservation system. Without this system, learning event sections with complicated resource requirements in high demand courses would simply be processed last. A simple "first come first served" assignment does not allow this to happen. (This latter requirement results from a desire not to get into the specification and costing of a large curriculum "scheduling" system whose purchase and design would necessarily be implied by any more ambitious allocation scheme.) The weakness of a reservation system simulated is that units are sometimes in demand, not in use, yet unavailable as they are "reserved" so that a section may collect its full complement of resources. This may be most realistic in the context of geographically decentralized resources with no centralized point of real-time control. However, if an item is very expensive, is centrally controlled, and is in high demand, chances are that it is more realistic to assume that some simple look-ahead is done so that requests for service that can be filled completely during a reservation period might be taken out of order rather than have the equipment sit idle. If this should be the case, this model is unable to simulate it. This particular aspect cannot be judged without an analysis of course types and the relative proportion of total courses simulated for which it creates a problem. These questions are outside the scope of this report.

In summary, whenever the model is unable to simulate a given course policy, course designs that attempt to incorporate such a policy will probably be at a disadvantage to designs that do not depend on these refinements and cause the comparison based on this model to be invalid.

VII. PROGRAM DOCUMENTATION

This section provides program documentation for the Resource Utilization Model in the form of a call tree (Fig. 6) and summaries of routine functions. Table 13 gives the names of these routines in alphabetical order along with an index number showing their position in the descriptions to follow. The model component descriptions are then presented in the order of their appearance in the call tree.

This section is supplemented by the source code from the model, which contains many descriptive comments. In particular, the Preamble to the code defines all global variables and data structures used by the model. It is therefore included in App. A.

Table 13

ALPHABETICAL POSITION INDEX

ABIL.INIT	(13)	P.C.GRPS	(5)
ARRIVAL (EVENT)	(15)	READ.COURSE	(6)
CHK.MAX.SECTN.SIZE	(9)	READ.INPUTS	(3)
CLASS.TIME	(29)	READ.RUNVARS	(4)
DEQUEUE	(31)	READ.RESOURCES	(8)
ELIGIBILITY	(18)	RECAP.COURSE	(10)
ENQUEUE	(26)	RECAP.RESOURCES	(11)
EVNT.INIT	(12)	REPORT (EVENT)	(37)
FIN.LE (EVENT)	(34)	REP2	(39)
FREE.RESOURCES	(30)	R.USE.UPDATE	(28)
GET.NEXT.LE	(17)	SCHED.LE	(27)
GET.RESOURCES	(25)	START.NEW.SECTION	(24)
GRADUATION (EVENT)	(35)	STOP.SIMULATION (EVENT)	(36)
HRS	(41)	SUBREP	(38)
INITIALIZE	(2)	TEST.RESULTS	(32)
JOIN.OR.SECTION	(19)	TEST.SETUP	(7)
JOIN.OQ.SECTION	(20)	TIME.R	(14)
MAIN	(1)	T.INTEGRALS	(40)
MIN.CHKR	(23)	TRY	(21)
MINS	(42)	TRY.HRDR	(22)
NEXT.MOVE	(16)	XOUT	(33)

(1) MAIN

Entry point of program. Calls initialization and input routines. Starts the simulation (this turns control over to TIME.R, the system clock routine).

(2) READ.INPUTS

Reads and sets trace flags if alpha[1] input precedes all other input. Calls other read routines. If failable tests are to be simulated, calls a routine to set up the failure probabilities by student category and by test. See Sec. V for a detailed specification of all input variables.

[1] This routine uses a Simscript function that can differentiate between alphabetic and numeric input.

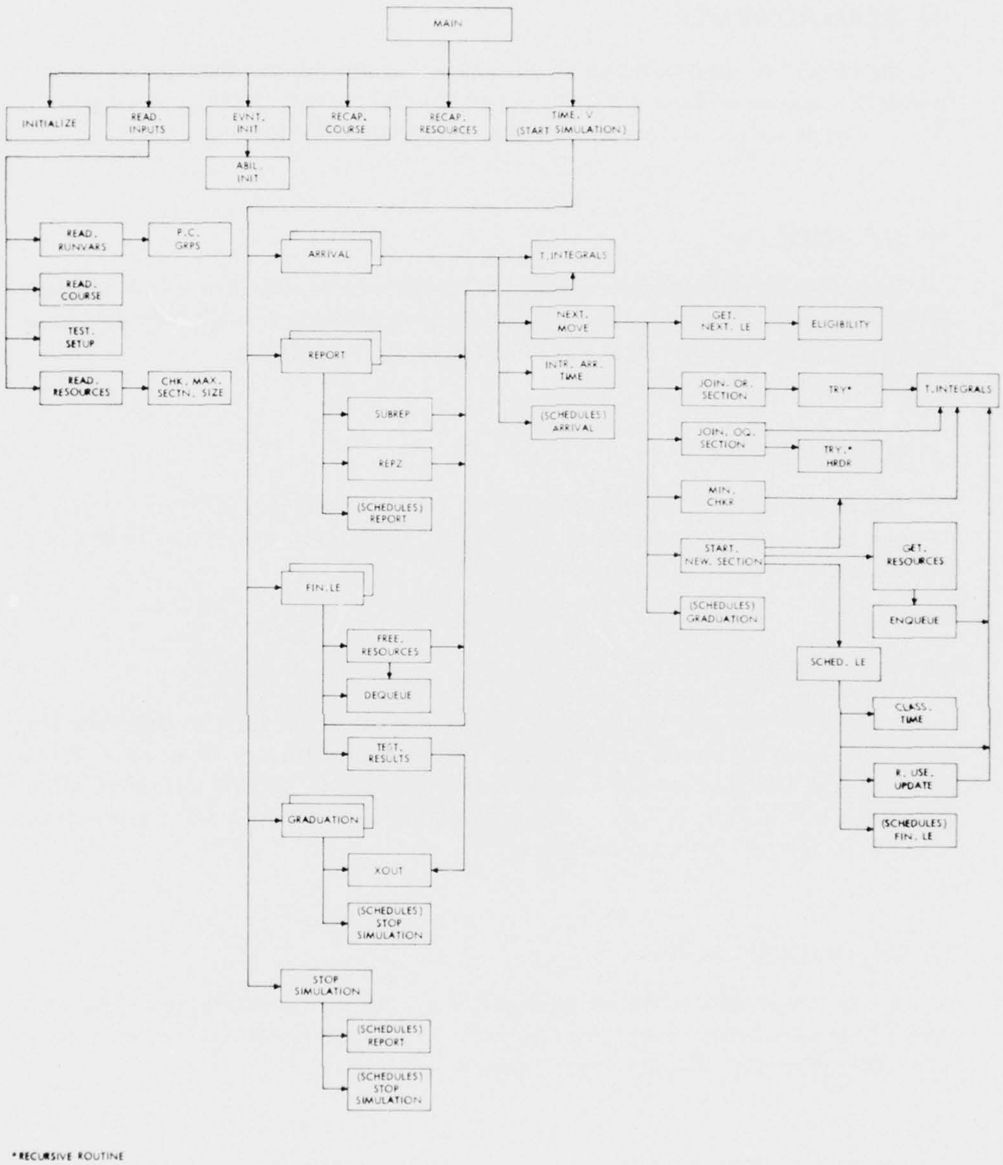

Fig. 6—Call tree

(3) **READ.RUNVARS**

Reads all the simulation input variables that are neither learning event nor resource attributes. These variables determine the general teaching strategies for the course as well as specifying run time parameters for the simulation.

(4) **P.C.GRPS**

Computes (from input values) the number of student categories to be simulated. Reserves arrays for storing report data by student category. Initializes the global array that gives the percentage of students in each category.

(5) **READ.COURSE**

Reads attributes of learning events and does error checking. Out-of-range values (see Sec. V) may be modified by the model or further processing may be stopped, depending on the severity of the error.

(6) **TEST.SETUP**

If failable tests are to be simulated, this routine is called to calculate the probabilities of failure at each failable test for each category of student. Some categories of students may be eligible for more or fewer failable tests than other categories of students. Not all student categories need have the same representation in the failing student population.

(7) **READ.RESOURCES**

Reads attributes of resources and creates a permanent entity representing each resource type to be simulated. Also does error checking. For a detailed description of the specifications of these input variables, see Sec. V.

(8) **CHK.MAX.SECTN.SIZE**

Checks the maximum section size specified for any learning event that uses any resource in limited supply (not unlimited). If necessary, modifies that maximum section size (maximum number of students that can be accommodated in a single section) downward as required by student capacity of the resource and resource quantities to be simulated.

(9) **RECAP.COURSE**

Prints all data related to students and learning events that have been read or calculated from input values. Prints warning lines if any out-of-range values had to be overridden during the input phase.

(10) RECAP.RESOURCES

Prints all data related to resources that were read or calculated from input values.

(11) EVNT.INIT

Schedules the first arrival of students at the course (at time 0). Schedules the first report, and if the simulation is to terminate after a fixed number of course hours also schedules the end of the simulation. Calls a routine to initialize the array containing the student ability level distribution, if students will be categorized by ability.

(12) ABIL.INIT

Converts the percent students desired in a category (input cumulatively, see variable UPPR.ABIL in Sec. V) to the upper ability level cutoff of students in that category. Uses a two-dimensional array, column one of which is the integral of the cumulative normal distribution and column 2 of which is the corresponding fractional number of standard deviations associated with each integral value. After finding the correct number of standard deviations, a standard deviation of .14 is used to compute the ability level. Thus .14 is a program constant.

(13) TIME.R

A system supplied routine is called when the statement START SIMULATION is encountered. It keeps a file of event notices sorted by time and by event priority and adds and removes from this file as events are scheduled or cancelled or executed. Time is incremented to the time of the next event and all events scheduled for that time are then executed.

(14) EVENT ARRIVAL

Schedules another arrival event at the current time plus the time between arrivals selected by the student arrival rule option (see variable SARO in Sec. V). Each arrival causes one or more student entities to be created. These students attempt to enter the course upon arrival. Ability levels are picked randomly from a normal distribution and assigned to these students at this time if that option has been chosen. A characteristic that can be a surrogate for any dichotomous description, such as male/female or pilot/non-pilot, may also be assigned. Students are then assigned to categories based on one or both of these assignments at the user's option.

(15) NEXT.MOVE

NEXT.MOVE is called when a student enters the course and after each student's completion of a learning event. At that time, the next move of a student will be graduation from the course or an attempt to join a section of the next learning event for which the student is eligible. If one or more sections of the next learning event have been formed but have not yet started, an attempt is made to put the student into one of these existing sections. This attempt may fail for one of several reasons:

a. The section has reached its maximum number of students.
b. The resources required to start the section without the student are now available, but if the student joined the section the additional resources required would not be available immediately.
c. The section is waiting for some resources but is not queued last for all resources for which it is waiting, and adding the student to the section would violate the basic allocation rule.

If the student fails to join an existing section, an attempt is made to form a new section. A new section can be formed if the minimum number of students required for a section of that learning event are ready to take the learning event. As students become ready, they will join a queue for other students waiting to take the learning event. When enough students have joined the queue, it is emptied, a section is formed, and the required resources are reserved or requested.

With each call to this routine, a student will be:

a. Scheduled for a graduation;
b. Assigned to a section that has all its resources and that will start immediately;
c. Assigned to a section that must wait for the release of some or all of the resources it requires; or
d. Assigned to a queue waiting for other students with whom to take the learning event.

(16) GET.NEXT.LE

Updates the next learning event number of the student by incrementing the current learning event number of the student or (if the student is about to recycle) by picking up the learning event number of the recycle point associated with the student's current learning event number. Calls ELIGIBILITY with the next learning event number of the student.

(17) ELIGIBILITY

Given the next possible learning event a student has not yet completed, tests the student's category (if students are being stratified by ability or other characteristic) against the learning event's characteristics to determine if the student should take the learning event. If the student is not eligible for that learning event, the

next sequential learning event in the course is similarly tested until either a match is found or it is determined that the student has completed all the learning events in the course for which the student is eligible.

(18) JOIN.OR.SECTION

Checks all sections of a learning event that are ready (have their resources and will start immediately) to determine if one more student can be accommodated in that section. If the section is not full, a routine is called to check all the resources that would be additionally required if the student should join the section. If the resource checks are successful, the student is assigned to the section.

(19) JOIN.OQ.SECTION

Checks all sections of a particular learning event that are waiting for resources to determine if one more student can be added to one of the sections. For each section of the appropriate learning event that is not full, a routine is called to see if additional resource requests can be added to the requests outstanding to accommodate one more student without violating model allocation rules. If the section is not full, a routine is called to make this resource check. If the resource checks are successsful, the student is added to the waiting section.

(20) TRY

Called once for each resource type used by a learning event. Determines if:

a. There are already enough resources assigned to this section for one more student, or
b. The amount required for one more student can be reserved because it is either unlimited or is available.

Calls itself recursively until all resource types needed have been examined or until there is a failure to reserve or create required resources.

(21) TRY.HRDR

Called once for each resource type used by a learning event. Determines if resources can be either reserved or requested without violating model allocation rules. Assumes that a section requiring this resource type is waiting for one of the resource types it requires and checks to see if this resource is the resource type in short supply. Calls itself recursively until all resource types needed have been examined or until there is a failure to obtain or request such a resource.

(22) MIN.CHKR

Adds a student to the appropriate queue for other students of a learning event. If the queue still contains less than the minimum students required for a section, the student is left in the queue. If the minimum can be satisfied, all students in the queue have their status changed so that a new section will be started.

(23) START.NEW.SECTION

Called whenever the number of students queued for other students at a learning event has reached the minimum to form a new section. Empties the queue and puts the students into a section of the learning event. If the minimum is also the maximum number of students allowed in one section of this learning event, then the full flag of the section is set. After the section is formed, calls are made to get the required resources for the section to proceed. If all required resources are available, a routine is called that starts up the learning event.

(24) GET.RESOURCES

This routine attempts to get the resources required for a section. The number of resources required will be determined by the capacities and other characteristics of the resources when used in this learning event. They depend as well on the number of students in the section at the time of allocation. As students are added after the initial resource allocations, those allocations are adjusted accordingly. This routine creates section-level records for managing the resources while they are in use. Resources will be reserved or requested or both as necessary to fulfill the section's requirements.

(25) ENQUEUE

When a section is unable to obtain (reserve) all the resources it needs, the section queues requests for each resource type needed. The section itself is queued at the learning event. This routine enqueues the section and files the students in the appropriate students' queue.

(26) SCHED.LE

Starts a learning event section that is ready to begin by changing the status of the students and updating their current learning event number. The event that will terminate the learning event section is also scheduled at the appropriate time. A routine is called to update the status of all the resources that have been reserved for use by the section.

(27) R.USE.UPDATE

As a section of a learning event begins, the status of all the resources it uses are changed from "reserved" to "in-use."

(28) CLASS.TIME

Determines what time interval should elapse between the start of a section of a learning event and its end. This may depend upon whether the learning event was intended for individual study. It also depends upon the minimum, maximum, and average times specified for sections of this learning event. Further, if that option has been selected, it may depend upon the ability level assigned to the student at entry to the course.

(29) FREE.RESOURCES

Changes the status of resource units being used by a section from "in-use" to "available." Calls a routine to handle any outstanding requests that may be queued for these resource units.

(30) DEQUEUE

Called for a resource type that has just had some capacity become available as the result of the ending of a section of a learning event. Checks the queue for requests for this resource and reserves all the new available capacity, if possible. As each new reservation is made, the section's other requests are examined to see if this additional allocation fulfills all of its requirements. If so, a routine will be called to start the section.

(31) TEST.RESULTS

This routine is called whenever the learning event that is being completed is a test—i.e., subject matter type of the learning event is TEST. Students may fail the course at this juncture if the test has been specified as failable for their category and they are taking the test for the first time (they are not recycling through it). Those students who may fail are selected randomly, and their average number over course time will be determined by user specification. Students may be recycled back from this learning event if the test is a recycle point and if they have not recycled the maximum number of times. Students who may be recycled are selected randomly also.

(32) XOUT

When a student fails or graduates the course, this routine cleans up the student record and updates report statistics.

(33) EVENT FIN.LE

This event signals the completion of a learning event by a section. The students are removed from the section and a routine is called for each student to ascertain the next move of that student. A routine is called to free the resources that were in use by the section. If the learning event being completed is a test a routine is called to check for failures and recycles.

(34) EVENT GRADUATION

Calculates the throughput time of the student through the course. Calls a routine to clean up the student's record. May schedule the end of the simulation if it is to depend on number of students graduated.

(35) EVENT STOP.SIMULATION

Ends the simulation. Schedules a report to be printed before the end if a report event did not already coincide with this event.

(36) EVENT REPORT

Prints information on the progress of students through the course and on the status of resource use at intervals selected by the user. Calls several routines that are merely extensions of this event and are broken out because of module length limitations. For a complete description of each variable and the report title under which it appears, see Sec. IV, Simulation Output Reports.

(37) SUBREP

An extension of the REPORT event.

(38) REP2

Also an extension of the REPORT event.

(39) T.INTEGRALS

This routine is called to update the cumulative time integrals of students in a learning event or a queue, and of resources in use. These are stored and updated for the generation of all averages over time and produced in the output reports. Whenever an element (e.g., student, resource, request) joins or leaves a queue, the course, or a section, this routine is called.

(40) HRS

Returns the truncated integer part of simulation time stored in decimal hours. Used in reports that print the time in hours and minutes.

(41) MINS

Returns the fractional portion of simulated time converted to minutes (from decimal hours). Used in reports that print the time in hours and minutes.

Appendix A

PREAMBLE (SIMSCRIPT II) TO MODEL CODE

```
PREAMBLE          LAST CCLUMN IS 72
''        ************************************************************
''        USE OF RANDOM NUMBER STREAMS TO GENERATE:
''
''        ABILITY LEVELS --                STREAM 1
''        FAILURES --                      STREAM 2
''        RECYCLES --                      STREAM 3
''        ARRIVAL GROUP SIZE --            STREAM 5
''        ARRIVAL TIME INTERVALS --        STREAM 9
''
''        ************************************************************

''        NOTE:  SIMULATION TIME IS IN DECIMAL HOURS.  CONVERTED TO
''               HOURS AND MINUTES FOR REPORT PURPOSES.

''        ************************************************************

''        TRACE INFORMATION:
''
''        THE MODEL WILL PRINT TRACE STATEMENTS IF ALL INPUT IS PRECEDED
''        WITH TRACE-FLAG-SETTING STATEMENTS OF THE FORM:
''              TRAC N
''        WHERE N IS A NUMBER FROM 1 TO 10.  THE TRACE FUNCTION OF EACH
''        NUMBER IS INDICATED BELOW.  (ADDITIONAL TRACE STATEMENTS MAY
''        BE ADDED AS NECESSARY FOR UNUSED TRACE FLAGS.  IF MORE THAN 10
''        ARE NECESSARY, THE TRASE ARRAY SHOULD BE ENLARGED.)
''        AS MANY TRACE-FLAG-SETTING STATEMENTS AS THERE ARE TRACE FLAGS
''        MAY BE SET AT ANY ONE TIME.  E.G.  TRAC 1  TRAC 3
''
''        1     EVENT TRACER.  THE SYSTEM VARIABLE 'BETWEEN.V' IS SET
''              TO ROUTINE E.TRACE WHICH IS CALLED JUST BEFORE ANY EVENT
''              IS ENTERED.
''        2     THE ABILITY, OTHER CHARACTERISTIC AND RESULTING GROUP
''              ARE PRINTED FOR EACH STUDENT AT ARRIVAL
''        3     STUDENTS GRADUATING OR FAILING ARE DESCRIBED AS TO
''              ABILITY, SPECIAL CHAR., GROUP, THROUGHPUT TIME OR AVERAGE
''              TIME BEFORE FAILURE.
''
''        4     CREATION OF UNLIMITED RESOURCES IS TRACED

''        5     DEQUEUE ROUTINE TRACE

''        6     TRACES RECYCLES AS THEY OCCUR IN TEST.RESULTS

''        7     TRACES USE OF RESOURCES
''
''**************************************************************
NORMALLY MODE IS INTEGER AND DIMENSION IS 0

''**************************************************************

''                       GLOBAL VARIABLES

''**************************************************************
THE SYSTEM HAS
        A SIM.END.OPT,       ''0 = RUN FOR ENDVAR SIMULATED HRS.
                             ''1 = RUN UNTIL ENDVAR STUDENTS ARE
```


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```
                               ''    GRADUATED OR DROPPED.
    AN ENDVAR,                 ''SEE SIM.END.DET
     A REPORT.INTERVAL,        ''TIME INTERVAL BETWEEN REPORTS IN
                               ''SIMULATED HRS.
    AN N.STUDENT,              ''CURRENT NUMBER OF STUDENTS IN COURSE
    AN NS.TI,                  ''TIME INTEGRAL OF STUDENTS
    AN NS.TI.TOLCH,            ''NS.TI TIME OF LAST CHANGE
    AN MX.ST.LOAD,             ''MAXIMUM STUDENT LOAD
    AN NGRADS,                 ''CUMULATIVE STUDENTS GRADUATED
    AN N.S.ARRVD,              ''CUMULATIVE STUDENTS ARRIVED
    AN NFAILS,                 ''CUMULATIVE NUMBER OF FAILURES
     A CR.RECYCLES,            ''CURRENT NUMBER OF STUDENTS RECYCLING
     A FAILRATE,               ''PERCENT STUDENTS WHO WILL FAIL COURSE
    AN AV.TBF,                 ''AN AVERAGE TIME BEFORE FAILURE IN
                               ''COURSE, OUTPUT VARIABLE.
     A SARO,                   ''STUDENT ARRIVAL RATE OPTION
                               ''1 - FIXED ARR. GROUP SIZE,
                               ''    FIXED INTER.ARRIVAL TIME
                               ''2 - RANDOM ARR GROUP SIZE,
                               ''    RANDOM INTER ARRIVAL TIME
                               ''3 - RANDOM ARR GROUP SIZE
                               ''    FIXED INTER ARRIVAL TIME
                               ''4 - FIXED ARRIVAL GROUPS SIZE
                               ''    RANDOM INTERARRIVAL TIME

    AN ARR.GRP.SZ,             ''NUMBER OF STUDENTS ARRIVING
                               ''AT THE COURSE AS A GROUP

    AN INTER.ARR.TIME,         ''MEAN TIME BETWEEN ARRIVALS(IN COURSE HOURS)
    AN ARR.G.DEV,              ''DEVIATION FROM ARRIVAL GROUP SIZE MEAN
    AN IAT.DEV,                ''DEVIATION FROM INTER.ARR.TIME FOR SARO=4
    AN ADAPT.POL,              ''0 - NO GROUPING OF STUDENTS BY ABILITY
                               ''    OR BACKGROUND.
                               ''1 - GROUPING BY 1 BACKGROUND CHAR. (2 GROUPS)
                               ''2 - GROUP BY ABILITY INTO 2 GROUPS
                               ''3 - GROUP BY ABILITY INTO 3 GROUPS
                               ''4 - GROUP BY ABILITY INTO 4 GROUPS
                               ''5 - GROUP BY ABILITY & BACKG. INTO 4 GRPS.
     A BG.PERC,                ''THE PERCENT STUDENTS WITH BACKGROUND CHAR.
     AN N.OBJ,                 ''THE NUMBER OF OBJECTIVES IN THE COURSE

    AN NVAR.CAPS,              ''NUMBER OF RESOURCE TYPES WITH VARYING
                               ''CAPACITY
    AN NVAR.SHR,               ''NUMBER OF RESOURCES WITH VARIABLE SHARING
                               ''POLICY.
     AND OWNS A NEW.ARRIVALS        ''STUDENTS

THE  SYSTEM OWNS A COURSE

''*********** REAL (GLOBAL) VARIABLES

DEFINE INTER.ARR.TIME,ARR.G.DEV,ARR.GRP.SZ,FAILRATE,BG.PERC,AV.TBF,
IAT.DEV, ENDVAR,REPORT.INTERVAL,TOT.THROUGHPUT.TIME, NS.TI,
    NS.TI.TOLCH AS REAL VARIABLES


''*********************************************************************

''                       GLOBAL ARRAYS

''*********************************************************************


DEFINE TRASE AS A 1-DIM ARRAY
DEFINE RESRC.REQMT.TABL, AD.POL,NVC,NVS    AS 2-DIM ARRAYS
DEFINE OBJ.NAME,EVD.ALPHA AS ALPHA 2-DIM ARRAYS
DEFINE UPPR.ABIL,PC.FAIL.GRP,PC.GRP,FREQ AS REAL 1-DIM ARRAYS
DEFINE BGNAME,EVD.KEY AS ALPHA 1-DIM ARRAYS
```

```
DEFINE ATFBG,ATHBG AS REAL 1-DIM ARRAYS
DEFINE ARRBG,NFLBG,NGRBG AS 1-DIM ARRAYS

''       TRASE IS AN ARRAY OF FLAGS USED FOR PROGRAM DEBUGGING
''       RESRC.REQMT.TABL IS AN INPUT TABLE N.LE.DESCRIPTOR X
''            N.RSOURCE.TYPE WITH ZEROES AND ONES TO INDICATE USE
''            OR NON-USE OF A RESOURCE FOR A PARTICULAR LE.
''       OBJ.NAME IS AN 8-CHAR NAME OF OBJECTIVE (INPUT VARIABLE)
''       AD.POL IS AN ARRAY OF CONSTANTS WHICH IS SET UP BEFORE
''            ADAPT.POL IS KNOWN.  IT GIVES THE NUMBER OF ABILITY GROUPS
''            AND NUMBER OF BACKGROUND GROUPS FOR EACH OPTION.
''       UPPR.ABIL,PC.FAIL.GRP,BGNAME ARE DEFINED IN INPUT REQUIREMENTS
''       PC.GRP IS DIMENSIONED ACCORDING TO THE NUMBER OF GROUPS.
''            EACH CELL GIVES PERCENT OF TOTAL STUDENTS WHICH THAT
''            GROUP REPRESENTS.
''       EVD.KEY IS A KEY TO LONGER VERSION OF EVENT DESCRIPTORS
''       NVC & NVS ARE INPUT TABLES WHICH GIVE FOR EACH LEARNING EVENT:
''       THE VARIABLE SHARING POLICY OR THE VARIABLE CAPACITY.  SEE
''       INPUT DEFINITIONS.

''      ATFBG,NFLBG,ATHBG,NGRBG,ARRBG ARE AVERAGE TIME TO FAILURE,
''      NO. OF FAILURES, NO. OF GRADUATIONS, NO. OF ARRIVALS: BY GROUP.

''*******************************************************************

''                              FUNCTIONS

''*******************************************************************


DEFINE INTR.ARR.TIME,CLASS.TIME,RNDUP  AS REAL FUNCTIONS
DEFINE HRS,MINS AS INTEGER FUNCTIONS
''*******************************************************************

''                               EVENTS

''*******************************************************************


EVENT NOTICES INCLUDE
         ARRIVAL,
         REPORT,
     AND STOP.SIMULATION

         EVERY GRADUATION HAS A STDT

         EVERY FIN.LE HAS    ''A SECTION
                   A DURATION,
                   A (LENO(1/2),
                     FULL.FLAG(2/2)),        ''TO SHOW NO MORE ADDING=
                   AND OWNS A STDNT.SET,
                   AND AN R.UNITS.USED ''SET OF R.SECT RECS, I.E.,
                                       ''RESOURCE USE RECORDS AT THE
                                       ''SECTION LEVEL
         PRIORITY ORDER IS  GRADUATION,
                   FIN.LE,
                   ARRIVAL,REPORT,STOP.SIMULATION
DEFINE DURATION AS A REAL VARIABLE

''*******************************************************************

''                    ENTITIES AND ATTRIBUTES

''*******************************************************************

PERMANENT ENTITIES


         EVERY LE.DESCRIPTOR HAS
''__________THE FOLLOWING ARE INPUTS:
                  AN (LENUMBER(1/2),          ''SEQUENCE NO.
                     OBJ.NUM(2/2)),      ''THE NUMBER CORRESPONDING TO THE
                                         ''OBJECTIVE NAME.
```

```
                A (SUBJ.MATTER.TYPE(1/2), ''FOR REPORTS
''                EVENT.DESCR(2/2),    ALPHA TO BE CONVERTED TO INDEX
                         ''P. - PRESENTATION
                         ''GP - GUIDED PRACTICE
                         ''UP - UNGUIDED PRACTICE
                         ''D. - DISCUSSION
                         ''CP - CHECK PRACTICE
                         ''H. - HOMEWORK (0.0 TIME ONLY)
                         ''R. - REVIEW
                         ''T. - TEST      THE ONLY ONE USED --
                                      ''REST ARE FOR REPORTS ONLY.
                  ED.NUM(2/2)),       ''EQUIV. TO OLD ALPHA EVENT.DESCR
                                      ''BUT NUMERIC, I.E.,"P." = 1 ...
                A (FLOW.CODE,
                         ''ONLY GROUP NUMBERS X'D BELOW MAY TAKE IF
                         ''FLOW CODE =  1...15

                ''       GRP 1   GRP2   GRP3   GRP4
                ''1        X
                ''2                X
                ''3        X       X
                ''4                       X
                ''5        X              X
                ''6                X      X
                ''7        X       X      X
                ''8                              X
                ''9        X                     X
                ''10               X             X
                ''11       X       X             X
                ''12                      X      X
                ''13       X              X      X
                ''14               X      X      X
                ''15       X       X      X      X
                ''NOTE:  IF ADAPT.POL = 0, ALL STUDENTS WILL BE
                ''PLACED IN GROUP 1 AND ALL FLOW CODES MUST BE 1.
                  GRP1(1/4),    ''EQUIV. TO FLOW.CODE AND CONVERTED
                  GRP2(2/4),    ''FOR INTERNAL USE.  THIS IS ALPHA
                  GRP3(3/4),    ''FOR REPORTS USE.
                  GRP4(4/4)),

               AN AVG.TIME.ALLWD,
                A (MAX.STUDENTS.ALLWD(1/2),       '' PER SECTION
                   MIN.NO.STUDENTS.REQD(2/2)),       ''PER SECTION
                A (MAX.TIME.MULT,    ''FOR CONSTRAINING THE
                  MAX.T.ALLWD),  ''INDIVIDUAL RATES OF PROGRESS
                                      ''EQUIVALENT, CONVERTED AT INPUT
                A (MIN.TIME.MULT,
                  MIN.T.ALLWD),
                A (P.FAILS,            ''0 = NO FAILURES AT THIS TEST
                                       ''1 = THIS IS A POTENTIAL FAIL
                                       ''    POINT FOR STUDENTS WHO
                                       ''    TAKE THE TEST.  SEE ROUTINE
                                       ''    TEST.SETUP FOR DESCRIPTION
                                       ''    OF PROBABILITY OF FAILURE.
                  EVENT.DESCR),         ''EQUIVALENCED FOR CONVENIENCE
                                        ''DISCARDED B/R E.FAILS IS READ
                A PC.RECYCLE,  ''PERCENT PASSING STUDENT TO RECYCLE
                A (NS.RECYCLING(1/2), ''CURRENT NUMBER OF STUDENTS IN
                                        ''LE WHO ARE RECYCLING.
                  LE.CUM.FAILDS(2/2)),''NUMBER OF FAILURES CAUSED BY
                                        ''THIS TEST (IF A TEST)
               AN (LEREC(1/2),  ''LE NUMBER TO RECYCLE TO
                  CUM.RECYCLES(3/4),  ''FROM THIS TEST (INCLUDES
                                        ''CURRENT RECYCLES.
                  MAX.NO.RECYCLES(4/4)),''(PER STUDENT) TO BE PER-
                                        ''MITTED FROM THIS POINT.
''----------THE FOLLOWING ARE OUTPUTS OR INTERNAL WORKING VARIABLES
                A (NO.SECTNS.IN.PROGRESS(1/2),
                  CUM.SECTIONS.COMPLTD(2/2)),
```

```
                    A  (CURR.NO.STUDENTS(1/2),
                       CUM.NO.STDTS(2/2)),        ''INCLUDES CURRENT STUDENTS
                    A CUM.TIME.INT,        ''OF STUDENTS OVER TIME
                    A TOT.TIME,            ''TO BE USED FOR NO-ZEROES AVG.
                    A T.OF.L.CH,           ''TIME OF LAST CHANGE IN INTEGRAL
                    A  (MAX.SECTN.SIZE.ACHIEVED(1/2),
                       CUMSKIPS(2/2)),
                    A  (MAX.CONCURR.SECTNS.ACHVD(1/2),
                       MAX.STDTS.ACHIEVED(2/2)), AND
                    A C.TI.GRPG.Q,         ''CUMULATIVE TIME INTEGRAL IN Q
                    A GPQ.TOLCH,           ''TIME OF LAST CHANGE IN GRPG Q
                    A  (MXN.READY.Q(1/2), ''NEEDED BECAUSE NUMBER IN Q
                                           ''DOES NOT REP NO.OF.STUDENTS
                       MXN.GRPG.Q(2/2)),
                    A C.TI.READY.Q,        ''TIME INTEG. OF READY Q
                    A RDQ.TOLCH,           ''TIME OF LAST CHANGE IN READY Q
                    A C.TT.READY.Q,        ''TOTAL TIME IN QUEUE,FOR
                                           ''NON-ZERO AVERAGES
                    A C.TT.GRPG.Q,         ''AS ABOVE
                    A  (C.S.GRPG.Q(1/2),         ''NO. OF ENTRIES IN Q
                       C.S.READY.Q(2/2)),
                   AN  (RQ.CZT.ENTRIES(1/2),         ''READY Q CUM. ZERO
                                                     ''TIME ENTRIES
                       GQ.CZ.ENTRIES(2/2)),              ''GRPG.Q CUM.ZERO TIME
                                                     ''ENTRIES
                   AN NLET.GRPG.Q,              ''GRPG.Q CUM. ZERO TIME
                                                     ''ENTRIES
                    A LET.GRPG.Q,                    ''LAST ENTRY TIME
          OWNS A STDS.GRPG.Q,        ''STUDENTS WAITING TO ASSEMBLE
                              ''THE MIN.NO.REQD. OR OTHER SUCH
          AND A STDTS.READY.Q,              ''WAITING FOR RESOURCES
          AND A SECTS.QD,           ''OF QD.SECTION(S) FOR RESOURCES

          AND A R.SRC.UTIL.SET,             ''INCLUDES LOCATIONS,MEDIA,
                                            ''HARDWARE,SOFTWARE,TA'S.
                                            ''SEE RECORD.RES.USE
          AND BELONGS TO A COURSE            ''OWNED BY SYSTEM
DEFINE AVG.TIME.ALLWD,MAX.TIME.MULT,MIN.TIME.MULT, CUM.TIME.INT,
    TOT.TIME,T.OF.L.CH,C.TI.GRPG.Q,GPQ.TOLCH,C.TI.READY.Q,
    RDQ.TOLCH,C.TT.READY.Q,C.TT.GRPG.Q,PC.RECYCLE,
    LET.GRPG.Q,P.FAILS,  ''READ INTEGER AND CONVERTED
    MAX.T.ALLWD,MIN.T.ALLWD
                    AS REAL VARIABLES
DEFINE EVENT.DESCR,GRP1,GRP2,GRP3,GRP4 AS ALPHA VARIABLES

          EVERY RSOURCE.TYPE HAS
                    A NAM1,
                    A NAM2,    ''AN 8-CHAR NAME FOR REPORT PURPOSES
                    A  (TYPE.ID.NO(1/2),
                       SHR.CODE(2/2)),
                              '' 1 - DEDICATED OVER ALL COURSE.
                              '' 2 - SHARED OVER ALL COURSE
                              '' 3 - DEDICATED AND SHARED, CODE 1 OR 2
                              ''        PROVIDED BY LEARNING EVENT
                              ''        IN NVS ARRAY
                    A CAP.CODE,            ''-1  UNDEFINED CAPACITY
                                           ''     DEFAULTS CAPACITY TO 1.
                                           '' 0  VARYING CAPACITY, TO
                                           ''     BE PROVIDED BY LE IN
                                           ''     NVC ARRAY
                                           '' N  THE CAPACITY = TO THE
                                           ''     NUMBER OF STUDENTS WHICH
                                           ''     CAN BE ACCOMMODATED BY 1
                                           ''     UNIT.

                    A  (QTY.CODE(1/2),           ''  0 QUANTITY IS UNLIMITED.
                                           ''   (MUST BE UNLIMITED IF CAPACITY
                                           ''    IS UNDEFINED).
                                           ''   N = THE LIMITED QUANTITY
```

```
              QTY.N.SYSTEM(2/2)),
            A QTY.RESERVED,
            A QTY.IN.USE,
            A QTY.AVAIL,
            A QTY.REQUESTED,
            A MX.N.USE,            ''MAX. IN SIMULTANEOUS USE
                                   ''NOTE DOES NOT INCLUDE
                                   ''RESERVED,JUST IN USE
            A C.TI.IN.USE,          ''CUMULATIVE TIME IN USE
           AN NUS.TOLCH,           ''TIME OFLAST CH IN C.TI.IN.USE
            A C.TT.IN.USE,         ''FOR NON-ZERO AVERAGES
            A C.TI.RSORC.Q,        ''TIME INTEGRAL OF RESOURCE QUEUE
           AN RSQ.TOLCH,           ''TIME OF LAST CH IN RSORC Q
            A C.S.RESORC.Q,        ''NO.OF ENTRIES
            A CZT.ENTRIES,         ''CUM.ZERO TIME ENTRIES IN RSORCQ
            A C.TT.RSORC.Q,        ''FOR NON-ZERO AVERAGES
            A MAX.NRSORC.Q,         ''MAXIMUM NO.OF SECTIONS
              A C.TI.IDLE,          ''CUMULATIVE TIME INTEGRAL OF
                                    ''FULLY IDLE UNITS
              A NIDLE.TOLCH,        ''TIME OF LAST CHANGE FOR
                                    ''NUMBER OF IDLE UNITS
              A NUS.IDLE            ''NUMBER OF UNITS NOW FULLY
                                    '' IDLE

            AND OWNS A RESORC.Q      ''OF RESRC.RESERV.REQS.

DEFINE NAM1,NAM2 AS ALPHA VARIABLES
DEFINE QTY.RESERVED,QTY.IN.USE,QTY.AVAIL,QTY.REQUESTED,
     MX.N.USE AS REAL VARIABLES
DEFINE C.TI.IN.USE,NUS.TOLCH,C.TT.IN.USE,C.TI.RSORC.Q,
   RSQ.TOLCH,C.TT.RSORC.Q, C.TI.IDLE, NIDLE.TOLCH  AS REAL VARIABLES

''*************************************************************

TEMPORARY ENTITIES

        EVERY RECORD.RES.USE HAS
                A (TYPE.NO(1/4),
                  LE.SHR.CODE(2/4), ''DED=1, SHRD=2; SEE SHR.CODE
                  ST.CAP.PER.UNIT(2/2)),
                A QQTY.IN.USE ,
                A QQTY.RSERVED ,
                A QQTY.REQUESTED ,
                A CUMIN.USE.HOURS,       ''BY THIS LE * # OF
                                   ''UNITS USED (FOR SINGLE
                                   ''USER CONSUMABLES)
                A REC.TOLCH,       ''TIME OF LAST CH IN
                                   ''CUMIN.USE.HOURS
                A CUM.STDT.USE.HOURS,
                                   ''AS ABOVE * # STUDENTS,
                                   ''FOR MULTIPLE USER TYPES
               AN MMX.N.USE        ''FOR THIS LE
        AND BELONGS TO A R.SRC.UTIL.SET   ''OWNED BY LE
DEFINE CUMIN.USE.HOURS, CUM.STDT.USE.HOURS,REC.TOLCH AS REAL VARIABLES

DEFINE QQTY.IN.USE,QQTY.RSERVED,QQTY.REQUESTED,
    MMX.N.USE AS REAL VARIABLES

        EVERY RSRC.RESERV.REQ HAS
                A SECT.ID          ''PTR TO A QD.SECTION
        AND BELONGS TO A RESORC.Q     ''OWNED BY RSOURCE.TYPE

        EVERY QD.SECTION HAS
                A Q.TIME,          ''TIME SECTION WAS QUEUED
                A QD.FINLE,        ''PTR TO A FIN.LE
        AND OWNS A REQUESTS.OS     ''REQUESTS OUTSTANDING
        AND BELONGS TO A SECTS.QD  ''OF THE LE
```

```
        EVERY OS.REQ HAS
                  A T.I.D,                ''A RESOURCE TYPE.ID.NO
              AND A QTY                   ''NUMBER STILL NEEDED
                                          ''TO START THE SECTION
        AND BELONGS TO A REQUESTS.OS      ''OF A QD.SECTION

        EVERY R.SECT.REC HAS
                 AN R.NO,                 ''RESOURCE TYPE ID.NO
                  A (QT.IN.USE,
                    QT.RESRVED),
                  AND BELONGS TO AN R.UNITS.USED ''OWNED BY A FIN.LE

DEFINE QT.IN.USE,QT.RESRVED AS REAL VARIABLES

DEFINE QTY AS A REAL VARIABLE

        EVERY STUDENT HAS
                 AN ARR.TIME,              ''AT THE COURSE
                  A (SPEC.CHAR(1/2),       ''0 DOES NOT HAVE IT
                                          ''1 HAS IT
                    GROUP(2/2)),          ''RANGE AND INTERPRETATION
                                          ''DEPENDS ON ADAPT.POL
                 AN ABIL.LEVEL,
                  A (CURRENT.LE.NO(1/2),
                    NEXT.LE.NO(2/2)),
                           ''FOR DEQUEUEING OR CONTINUING
                  A (STATUS(1/4),
                           '' 0 =
                           '' 3 = QUEUED FOR MIN. STUDENTS
                           '' 4 = QUEUED FOR RESOURCE
                           '' 5 = IN A LE
                           ''8 = READY TO GRADUATE
                           ''11  IN A MIN.Q READY TO GO
                           ''12  ABOUT TO RECYCLE

                    REC.FROM(2/2)),       ''THE TEST BEING RECYCLED FROM
                                          ''IF RECYCLING.
        AND BELONGS TO
                  A NEW.ARRIVALS,
                  A STDS.GRPG.Q,          ''WAITING FOR MIN STDTS
                                          ''TO ASSEMBLE FOR L.E.
                  A STDTS.READY.Q,        ''WAITING FOR RESOURCE SET
                                          ''OWNED BY LE.DESCRIPTOR
                  A STDNT.SET             ''OWNED BY FIN.LE
        AND OWNS
                  A RECRD.RECYCLES

EVERY RCYCLE.REC HAS
                 AN (ID.LE(1/2),          ''MUST BE TEST, OF COURSE.
                     COUNT(2/2)),
        AND BELONGS TO A RECRD.RECYCLES             ''OWNED BY STUDENT


DEFINE ABIL.LEVEL AS A  REAL VARIABLE
DEFINE NEW.ARRIVALS,COURSE,STDNT.SET,
   STDS.GRPG.Q,RESORC.Q,R.SPC.UTIL.SET,
   STDTS.READY.Q,REQUESTS.OS,SECTS.QD,RECRD.RECYCLES AS A SET WITHOUT
        FB,FA,PF,RL ROUTINES
NORMALLY TYPE IS SAVED
END
```

Appendix B

OUTPUT REPORTS FOR SAMPLE CASE

R E S O U R C E   U T I L I Z A T I O N   M O D E L

<----- S U M M A R Y   O F   I N I T I A L   C O N D I T I O N S ----->
—P A R T 1—

REPORTS: REPORTS WILL BE PRINTED EVERY 768.00 COURSE HOURS.

SIMULATION TERMINATION: SIMULATION OF THE COURSE WILL TERMINATE AFTER 768.00 COURSE HOURS.

STUDENT ARRIVALS AT COURSE:
8 STUDENTS WILL ARRIVE AT THE COURSE EVERY 30 COURSE HOURS.

STUDENT GROUPING POLICY:

STUDENTS WILL BE ASSIGNED TO 1 OF 4 CATEGORIES:

CATEGORY NUMBER	PERCENT STUDENTS	CATEGORY COMPOSITION
1	.28	SLOW STUDENTS WITHOUT E.E.TNG.
2	.12	SLOW STUDENTS WITH E.E.TNG.
3	.42	FAST STUDENTS WITHOUT E.E.TNG.
4	.18	FAST STUDENTS WITH E.E.TNG.

COURSE.FAILURE POLICY:

85.00 PER CENT OF THE STUDENTS ENTERING THIS COURSE WILL COMPLETE IT SATISFACTORILY. 15.00 PER CENT WILL FAIL.

STUDENT FAILURES WILL BE RELATED TO STUDENT CATEGORIES AS FOLLOWS:

50.0 PER CENT OF THE FAILURES WILL BE FROM CATEGORY 1 (WHICH CONTAINS 28.00 PER CENT OF THE STUDENT POPULATION).
30.0 PER CENT OF THE FAILURES WILL BE FROM CATEGORY 2 (WHICH CONTAINS 12.00 PER CENT OF THE STUDENT POPULATION).
10.0 PER CENT OF THE FAILURES WILL BE FROM CATEGORY 3 (WHICH CONTAINS 42.00 PER CENT OF THE STUDENT POPULATION).
10.0 PER CENT OF THE FAILURES WILL BE FROM CATEGORY 4 (WHICH CONTAINS 18.00 PER CENT OF THE STUDENT POPULATION).

R E S O U R C E   U T I L I Z A T I O N   M O D E L

<-----   S U M M A R Y   O F   I N I T I A L   C O N D I T I O N S ----->

—P A R T 2—

##

SUBJECT MATTER CODES

1. EASY FACTS AND CONCEPTS
2. DIFFICULT FACTS AND CONCEPTS
3. SIMPLE CLASSROOM SKILLS (SELECTED RESPONSE)
4. SIMPLE CLASSROOM SKILLS (CONSTRUCTED RESPONSE)
5. COMPLEX CLASSROOM SKILLS (SELECTED RESPONSE)
6. COMPLEX CLASSROOM SKILLS (CONSTRUCTED FESPONSE)
7. TEAM SKILLS WITH SPECIAL RESOURCES
8. INDIVIDUAL SKILLS WITH SPECIAL RESOURCES (PRODUCT ONLY)
9. INDIVIDUAL SKILLS WITH SPECIAL RESOURCES (PROCESS ONLY)
10. INDIVIDUAL SKILLS WITH SPECIAL RESOURCES (PRODUCT AND PROCESS)

##

RESOURCE UTILIZATION MODEL -- COURSE TO BE SIMULATED:

L.E. NO.	OBJECTIVE	SUBJECT MATTER CODE (SEE P.2)	EVENT DESCRIPTOR	CATEGORIES ELIGIBLE	MAX. STDTS. ALLWD.	MIN. STDTS. REQD.	(HRS.:MINUTES) MAX. TIME ALLWD.	AVG. TIME ALLWD.	MIN. TIME ALLWD.	FAIL-ABLE?	PERCENT STDTS TO RECYCLE	RECYCLE TO L.E. NO.	MAXIMUM RECYCLES
1	TESTEQP.	1	PRESENTATION	1	6	2	1:30	1:30	1:30		0.	0	0
2	TESTEQP.	1	HOMEWORK	1	1	1	0: 0	0: 0	0: 0		0.	0	0
3	TESTEQP.	2	PRESENTATION	1	6	2	1: 0	1: 0	1: 0		0.	0	0
4	TESTEQP.	2	HOMEWORK	1	1	1	0: 0	0: 0	0: 0		0.	0	0
5	URN5CHAR	2	PRESENTATION	1	6	2	2: 0	2: 0	2: 0		0.	0	0
6	URN5CHAR	2	HOMEWORK	1	1	1	0: 0	0: 0	0: 0		0.	0	0
7	URN5CHAR	6	GUID. PRACT.	1	6	2	1:50	1:50	1:50		0.	0	0
8	URN5CHAR	6	UNGUID.PRACT	1	6	2	3:40	3:40	3:40		0.	0	0
9	URN5CHAR	6	DISCUSSION	1	6	2	0:30	0:30	0:30		0.	0	0
10	URN5CHAR	6	HOMEWORK	1	1	1	0: 0	0: 0	0: 0		0.	0	0
11	SERVROUT	7	UNGUID.PRACT	1	8	2	0:30	0:30	0:30		0.	0	0
12	URN5CHAR	6	GUID. PRACT.	1	6	2	1:50	1:50	1:50		0.	0	0
13	URN5CHAR	6	UNGUID.PRACT	1	6	2	3:40	3:40	3:40		0.	0	0
14	URN5CHAR	6	DISCUSSION	1	6	2	0:30	0:30	0:30		0.	0	0
15	URN5CHAR	6	HOMEWORK	1	1	1	0: 0	0: 0	0: 0		0.	0	0
16	SERVROUT	7	UNGUID.PRACT	1	8	2	1:30	1:30	1:30		0.	0	0
17	TBSHPRIN	1	PRESENTATION	1	6	2	0:30	0:30	0:30		0.	0	0
18	TBSHPRIN	1	HOMEWORK	1	1	1	0: 0	0: 0	0: 0		0.	0	0
19	TBSHPRIN	2	PRESENTATION	1	6	2	1: 0	1: 0	1: 0		0.	0	0
20	TBSHPRIN	2	HOMEWORK	1	1	1	0: 0	0: 0	0: 0		0.	0	0
21	TBSHURN5	7	UNGUID.PRACT	1	8	2	1:30	1:30	1:30		0.	0	0
22	FLTCHK..	1	PRESENTATION	1	6	2	0:30	0:30	0:30		0.	0	0
23	FLTCHK..	1	HOMEWORK	1	1	1	0: 0	0: 0	0: 0		0.	0	0
24	INSTALL.	1	PRESENTATION	1	6	2	0:30	0:30	0:30		0.	0	0
25	INSTALL.	1	HOMEWORK	1	1	1	0: 0	0: 0	0: 0		0.	0	0
26	REVIEW1.	6	REVIEW	1	6	2	0:30	0:30	0:30		0.	0	0
27	EXAM1...	6	TEST	1	6	2	0:30	0:30	0:30		0.	0	0
28	EXAM1...	7	TEST	1	8	2	0:30	0:30	0:30		0.	0	0
29	CRITQ1..	1	TEST	1	6	2	0:15	0:15	0:15	YES	20.00	1	2
30	TESTEQP.	1	PRESENTATION	3	1	1	1: 7	1: 7	1: 7		0.	0	0
31	TESTEQP.	1	HOMEWORK	3	1	1	0: 0	0: 0	0: 0		0.	0	0
32	TESTEQP.	2	PRESENTATION	3	1	1	0:45	0:45	0:45		0.	0	0
33	TESTEQP.	2	HOMEWORK	3	1	1	0: 0	0: 0	0: 0		0.	0	0
34	URN5CHAR	2	PRESENTATION	3	1	1	1:29	1:29	1:29		0.	0	0
35	URN5CHAR	2	HOMEWORK	3	1	1	0: 0	0: 0	0: 0		0.	0	0
36	URN5CHAR	6	GUID. PRACT.	3	1	1	1:35	1:35	1:35		0.	0	0
37	URN5CHAR	6	UNGUID.PRACT	3	1	1	4:11	4:11	4:11		0.	0	0
38	URN5CHAR	6	DISCUSSION	3	6	2	0:24	0:24	0:24		0.	0	0
39	URN5CHAR	6	HOMEWORK	3	1	1	0: 0	0: 0	0: 0		0.	0	0
40	SERVROUT	7	UNGUID.PRACT	3	8	2	0:30	0:30	0:30		0.	0	0
41	URN5CHAR	6	GUID. PRACT.	3	1	1	1:35	1:35	1:35		0.	0	0
42	URN5CHAR	6	UNGUID.PRACT	3	1	1	4:11	4:11	4:11		0.	0	0
43	URN5CHAR	6	DISCUSSION	3	6	2	0:24	0:24	0:24		0.	0	0
44	URN5CHAR	6	HOMEWORK	3	1	1	0: 0	0: 0	0: 0		0.	0	0
45	SERVROUT	7	UNGUID.PRACT	3	8	2	1:30	1:30	1:30		0.	0	0
46	TBSHPRIN	1	PRESENTATION	3	1	1	0:23	0:23	0:23		0.	0	0

R E S O U R C E   U T I L I Z A T I O N   M O D E L -- C O U R S E   T O   B E   S I M U L A T E D:

L.E. NO.	OBJECTIVE	SUBJECT MATTER CODE (SEE P.2)	EVENT DESCRIPTOR	CATEGORIES ELIGIBLE	MAX. STDTS. ALLWD.	MIN. STDTS. REQD.	(HRS.:MINUTES) MAX. TIME ALLWD.	AVG. TIME ALLWD.	MIN. TIME ALLWD.	FAIL-ABLE?	PERCENT STDTS TO RECYCLE	RECYCLE TO L.E. NO.	MAXIMUM RECYCLES
47	TBSHPRIN	1	HOMEWORK	3	1	1	0: 0	0: 0	0: 0		0.	0	0
48	TBSHPRIN	2	PRESENTATION	3	1	1	0:45	0:45	0:45		0.	0	0
49	TBSHPRIN	2	HOMEWORK	3	1	1	0: 0	0: 0	0: 0		0.	0	0
50	TBSHURN5	7	UNGUID.PRACT	3	8	2	1:30	1:30	1:30		0.	0	0
51	FLTCHK..	1	PRESENTATION	3	1	1	0:23	0:23	0:23		0.	0	0
52	FLTCHK..	1	HOMEWORK	3	1	1	0: 0	0: 0	0: 0		0.	0	0
53	INSTALL.	1	PRESENTATION	3	1	1	0:23	0:23	0:23		0.	0	0
54	INSTALL.	1	HOMEWORK	3	1	1	0: 0	0: 0	0: 0		0.	0	0
55	EXAM1...	6	TEST	3	1	1	0:30	0:30	0:30		0.	0	0
56	EXAM1...	7	TEST	3	8	2	0:30	0:30	0:30		0.	0	0
57	CRITQ1..	1	TEST	3	6	2	0:15	0:15	0:15	YES	5.00	30	2
58	TESTEQP.	2	PRESENTATION	2	1	1	0:45	0:45	0:45		0.	0	0
59	TESTEQP.	2	HOMEWORK	2	1	1	0: 0	0: 0	0: 0		0.	0	0
60	URN5CHAR	2	PRESENTATION	2 4	1	1	1:29	1:29	1:29		0.	0	0
61	URN5CHAR	2	HOMEWORK	2 4	1	1	0: 0	0: 0	0: 0		0.	0	0
62	URN5CHAR	6	GUID. PRACT.	2 4	1	1	1:35	1:35	1:35		0.	0	0
63	URN5CHAR	6	UNGUID.PRACT	2 4	1	1	4:11	4:11	4:11		0.	0	0
64	URN5CHAR	6	DISCUSSION	2 4	6	2	0:24	0:24	0:24		0.	0	0
65	URN5CHAR	6	HOMEWORK	2 4	1	1	0: 0	0: 0	0: 0		0.	0	0
66	SERVROUT	7	UNGUID.PRACT	2 4	8	2	0:30	0:30	0:30		0.	0	0
67	URN5CHAR	6	GUID. PRACT.	2 4	1	1	1:35	1:35	1:35		0.	0	0
68	URN5CHAR	6	UNGUID.PRACT	2 4	1	1	4:11	4:11	4:11		0.	0	0
69	URN5CHAR	6	DISCUSSION	2 4	6	2	0:24	0:24	0:24		0.	0	0
70	URN5CHAR	6	HOMEWORK	2 4	1	1	0: 0	0: 0	0: 0		0.	0	0
71	SERVROUT	7	UNGUID.PRACT	2 4	8	2	1:30	1:30	1:30		0.	0	0
72	TBSHPRIN	1	PRESENTATION	2 4	1	1	0:23	0:23	0:23		0.	0	0
73	TBSHPRIN	1	HOMEWORK	2 4	1	1	0: 0	0: 0	0: 0		0.	0	0
74	TBSHPRIN	2	PRESENTATION	2 4	1	1	0:45	0:45	0:45		0.	0	0
75	TBSHPRIN	2	HOMEWORK	2 4	1	1	0: 0	0: 0	0: 0		0.	0	0
76	TBSHURN5	7	UNGUID.PRACT	2 4	8	2	1:30	1:30	1:30		0.	0	0
77	FLTCHK..	1	PRESENTATION	2 4	1	1	0:23	0:23	0:23		0.	0	0
78	FLTCHK..	1	HOMEWORK	2 4	1	1	0: 0	0: 0	0: 0		0.	0	0
79	INSTALL.	1	PRESENTATION	2 4	1	1	0:23	0:23	0:23		0.	0	0
80	INSTALL.	1	HOMEWORK	2 4	1	1	0: 0	0: 0	0: 0		0.	0	0
81	REVIEW1.	6	REVIEW	2	6	2	0:30	0:30	0:30		0.	0	0
82	EXAM1...	6	TEST	2 4	1	1	0:30	0:30	0:30		0.	0	0
83	EXAM1...	7	TEST	2 4	8	2	0:30	0:30	0:30		0.	0	0
84	CRITQ1..	1	TEST	2 4	6	2	0:15	0:15	0:15	YES	5.00	58	2

RESOURCE UTILIZATION MODEL--RESOURCE TYPES TO BE USED

RESOURCE NO.	RESOURCE NAME	QUANTITY LIMITED	QUANTITY UNLIMITED	INITIAL QUANTITY ON HAND	ACROSS-SECTION SHARING POLICY FIXED	ACROSS-SECTION SHARING POLICY VARIABLE	CAPACITY PER UNIT FIXED	CAPACITY PER UNIT VARIABLE	CAPACITY (STUDENTS PER UNIT) IF FIXED CAPACITY
1	ANURN5..	X		4	DED		FIX		2
2	TSNR1...	X		4	DED		FIX		2
3	TSNR2...	X		4	DED		FIX		2
4	SIGGEN..	X		4	DED		FIX		2
5	INSTRCTR	X		2		VAR		VAR	
6	EVALUATR	X		2	DED			VAR	
7	RM2.MON	X		1	SHR		FIX		12
8	RM3.MON	X		1	SHR		FIX		12
9	LAB.MON	X		2	SHR		FIX		6
10	ROOM1...	X		2		VAR	FIX		6
11	ROOM2...	X		1		VAR	FIX		12
12	ROOM3...	X		1		VAR	FIX		12
13	LAB.....	X		1	SHR		FIX		20
14	I.SV....	X		2	DED		FIX		6
15	L.ASV...		X	0	DED		FIX		1
16	L.SV....	X		34	DED		FIX		1
17	P.SV....	X		8	DED		FIX		1

RESOURCE UTILIZATION MODEL—RESOURCES REQUIRED BY LEARNING EVENT

L.E.NO.	RESOURCE NO.	RESOURCE NAME	SHRD/DED	CAPACITY (STUDENTS PER UNIT)
1				
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
	14	I.SV....	DED.	6
3				
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
	14	I.SV....	DED.	6
5				
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
	14	I.SV....	DED.	6
7				
	5	INSTRCTR	DED.	4
	10	ROOM1...	DED.	6
8				
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
9				
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
	14	I.SV....	DED.	6
11				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	9	LAB.MON	SHRD	6
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
12				
	5	INSTRCTR	DED.	4
	10	ROOM1...	DED.	6
13				
	5	INSTRCTR	DED.	6
	10	ROOM1...	SHRD	6
14				

RESOURCE UTILIZATION MODEL — RESOURCES REQUIRED BY LEARNING EVENT

L.E.NO.	RESOURCE NO.	RESOURCE NAME	SHRD/DED	CAPACITY (STUDENTS PER UNIT)
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
	14	I.SV....	DED.	6
16				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	9	LAB.MON	SHRD	6
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
17				
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
	14	I.SV....	DED.	6
19				
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
	14	I.SV....	DED.	6
21				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	9	LAB.MON	SHRD	6
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
22				
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
	14	I.SV....	DED.	6
24				
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
	14	I.SV....	DED.	6
26				
	5	INSTRCTR	DED.	6
	10	ROOM1...	DED.	6
	14	I.SV....	DED.	6

RESOURCE UTILIZATION MODEL — RESOURCES REQUIRED BY LEARNING EVENT

L.E.NO.	RESOURCE NO.	RESOURCE NAME	SHRD/DED	CAPACITY (STUDENTS PER UNIT)
27				
	5	INSTRCTR	SHRD	16
	10	ROOM1...	SHRD	6
	16	L.SV....	DED.	1
28				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	6	EVALUATR	DED.	4
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
29				
	5	INSTRCTR	DED.	6
	6	EVALUATR	DED.	6
	10	ROOM1...	DED.	6
30				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
	17	P.SV....	DED.	1
32				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
	17	P.SV....	DED.	1
34				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
	17	P.SV....	DED.	1
36				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
	16	L.SV....	DED.	1
37				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
38				
	5	INSTRCTR	DED.	6
	11	ROOM2...	DED.	12
	14	I.SV....	DED.	6

RESOURCE UTILIZATION MODEL — RESOURCES REQUIRED BY LEARNING EVENT

L.E.NO.	RESOURCE NO.	RESOURCE NAME	SHRD/DED	CAPACITY (STUDENTS PER UNIT)
40				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	9	LAB.MON	SHRD	6
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
41				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
	16	L.SV....	DED.	1
42				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
43				
	5	INSTRCTR	DED.	6
	11	ROOM2...	DED.	12
	14	I.SV....	DED.	6
45				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	9	LAB.MON	SHRD	6
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
46				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
	17	P.SV....	DED.	1
48				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
	17	P.SV....	DED.	1
50				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2

RESOURCE UTILIZATION MODEL — RESOURCES REQUIRED BY LEARNING EVENT

L.E.NO.	RESOURCE NO.	RESOURCE NAME	SHRD/DED	CAPACITY (STUDENTS PER UNIT)
	4	SIGGEN..	DED.	2
	9	LAB.MON	SHRD	6
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
51				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
	17	P.SV....	DED.	1
53				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
	17	P.SV....	DED.	1
55				
	7	RM2.MON	SHRD	12
	11	ROOM2...	SHRD	12
	16	L.SV....	DED.	1
56				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	6	EVALUATR	DED.	4
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
57				
	5	INSTRCTR	DED.	6
	6	EVALUATR	DED.	6
	11	ROOM2...	DED.	12
58				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12
	17	P.SV....	DED.	1
60				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12
	17	P.SV....	DED.	1
62				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12

AD-A044 159 RAND CORP SANTA MONICA CALIF F/G 5/1
MODIA: VOLUME 4. THE RESOURCE UTILIZATION MODEL.(U)
JUL 77 M GALLEGOS F49620-77-C-0023
UNCLASSIFIED R-1703-AF NL

2 OF 2
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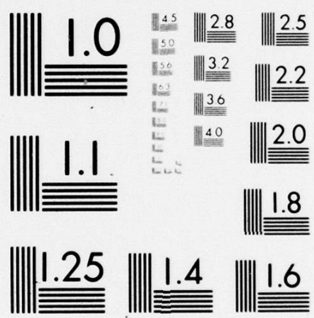

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

RESOURCE UTILIZATION MODEL—RESOURCES REQUIRED BY LEARNING EVENT

L.E.NO.	RESOURCE NO.	RESOURCE NAME	SHRD/DED	CAPACITY (STUDENTS PER UNIT)
	16	L.SV....	DED.	1
63				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12
64				
	5	INSTRCTR	DED.	6
	12	ROOM3...	DED.	12
	14	I.SV....	DED.	6
66				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	9	LAB.MON	SHRD	6
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
67				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12
	16	L.SV....	DED.	1
68				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12
69				
	5	INSTRCTR	DED.	6
	12	ROOM3...	DED.	12
	14	I.SV....	DED.	6
71				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	9	LAB.MON	SHRD	6
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
72				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12
	17	P.SV....	DED.	1

RESOURCE UTILIZATION MODEL — RESOURCES REQUIRED BY LEARNING EVENT

L.E.NO.	RESOURCE NO.	RESOURCE NAME	SHRD/DED	CAPACITY (STUDENTS PER UNIT)
74				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12
	17	P.SV....	DED.	1
76				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	9	LAB.MON	SHRD	6
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
77				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12
	17	P.SV....	DED.	1
79				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12
	17	P.SV....	DED.	1
81				
	5	INSTRCTR	DED.	6
	12	ROOM3...	DED.	12
	14	I.SV....	DED.	6
82				
	8	RM3.MON	SHRD	12
	12	ROOM3...	SHRD	12
	16	L.SV....	DED.	1
83				
	1	ANURN5..	DED.	2
	2	TSNR1...	DED.	2
	3	TSNR2...	DED.	2
	4	SIGGEN..	DED.	2
	6	EVALUATR	DED.	4
	13	LAB.....	SHRD	20
	16	L.SV....	DED.	1
84				
	5	INSTRCTR	DED.	6
	6	EVALUATR	DED.	6

RESOURCE UTILIZATION MODEL—RESOURCES REQUIRED BY LEARNING EVENT

L.E.NO.	RESOURCE NO.	RESOURCE NAME	SHRD/DED	CAPACITY (STUDENTS PER UNIT)
	12	ROOM3...	DED.	12

RESOURCE UTILIZATION MODEL

CROSS REFERENCE TABLE—LEARNING EVENTS BY RESOURCE TYPE

RESOURCE NO./NAME	LEARNING EVENTS WHICH USE THIS RESOURCE:
1 ANURN5..	11 16 21 28 40 45 50 56 66 71 76 83
2 TSNR1...	11 16 21 28 40 45 50 56 66 71 76 83
3 TSNR2...	11 16 21 28 40 45 50 56 66 71 76 83
4 SIGGEN..	11 16 21 28 40 45 50 56 66 71 76 83
5 INSTRCTR	1 3 5 7 8 9 12 13 14 17 19 22 24 26 27 29 38 43 57 64 69 81 84
6 EVALUATR	28 29 56 57 83 84
7 RM2.MON	30 32 34 36 37 41 42 46 48 51 53 55
8 RM3.MON	58 60 62 63 67 68 72 74 77 79 82
9 LAB.MON	11 16 21 40 45 50 66 71 76
10 ROOM1...	1 3 5 7 8 9 12 13 14 17 19 22 24 26 27 29
11 ROOM2...	30 32 34 36 37 38 41 42 43 46 48 51 53 55 57
12 ROOM3...	58 60 62 63 64 67 68 69 72 74 77 79 81 82 84
13 LAB.....	11 16 21 28 40 45 50 56 66 71 76 83
14 I.SV....	1 3 5 9 14 17 19 22 24 26 38 43 64 69 81
15 L.ASV...	
16 L.SV....	11 16 21 27 28 36 40 41 45 50 55 56 62 66 67 71 76 82 83
17 P.SV....	30 32 34 46 48 51 53 58 60 72 74 77 79

TIME = 768: 0 (HOURS,MINUTES) ______ R E P O R T ______ RESOURCE UTILIZATION MODEL

NUMBER OF ARRIVALS = 208

NUMBER OF GRADUATES = 175

NUMBER OF FAILURES = 22

CURRENT NUMBER OF STUDENTS = 11

AVERAGE TIME BEFORE FAILURE = 28:43

CURRENT STUDENTS RECYCLING = 1

AVERAGE STUDENT LOAD = 8.3

PEAK STUDENT LOAD = 13.0

AVERAGE TIME TO FINISH COURSE = 30:51

<<<< CATEGORIES >>>>

CATEGORY NO.	CUMULATIVE NUMBER OF STUDENTS ARRIVED /	FAILED /	GRADUATED	AVERAGE TIME TO FAILURE	/ FINISH COURSE
1	62	12	49	31:57	35:48
2	22	2	15	37: 5	52:31
3	85	2	78	22:20	25:15
4	39	6	33	21:37	26:51

TIME = 768: 0 (HOURS,MINUTES)

----- STUDENTS AND SECTIONS BY LEARNING EVENT NUMBER ----

LE. NO.	OBJECTIVE	EVENT DESCRIPTOR	ELIG. CATE-GORIES	CUMULATIVE STU-DENT ENTRIES	CUMULATIVE SEC-TIONS COMPLTD	CUMULATIVE STU-DENT SKIPS	AVG. NO.OF STDTS	AVERAGE TIME PER STUDENT	MAXIMUM SECTION SIZE ACHIEVED	MAXIMUM NO.OF STDTS.	MAXIMUM NO.OF CONCURRENT SECTIONS	(IF TEST) CUMULATIVE FAILS	(IF TEST) CUMULATIVE RECYCLES	CURRENT STU-DENTS	CURRENT SEC-TION
1	TESTEQP.	PRESENTATION	1	73	22	146	3.32	1:30	5	5	1	0	0	0	0
2	TESTEQP.	HOMEWORK	1	73	73	146	0.	0: 0	1	0	0	0	0	0	0
3	TESTEQP.	PRESENTATION	1	73	22	146	3.32	1: 0	5	5	1	0	0	0	0
4	TESTEQP.	HOMEWORK	1	73	73	146	0.	0: 0	1	0	0	0	0	0	0
5	URN5CHAR	PRESENTATION	1	73	22	146	3.32	2: 0	5	5	1	0	0	0	0
6	URN5CHAR	HOMEWORK	1	73	73	146	0.	0: 0	1	0	0	0	0	0	0
7	URN5CHAR	GUID. PRACT.	1	73	22	146	3.32	1:50	5	5	1	0	0	0	0
8	URN5CHAR	UNGUID.PRACT	1	73	22	146	3.32	3:40	5	5	1	0	0	0	0
9	URN5CHAR	DISCUSSION	1	73	23	146	3.30	0:30	5	5	2	0	0	0	0
10	URN5CHAR	HOMEWORK	1	73	73	146	0.	0: 0	1	0	0	0	0	0	0
11	SERVROUT	UNGUID.PRACT	1	73	22	146	3.32	0:30	5	5	1	0	0	0	0
12	URN5CHAR	GUID. PRACT.	1	73	22	146	3.32	1:50	5	5	1	0	0	0	0
13	URN5CHAR	UNGUID.PRACT	1	73	22	146	3.32	3:40	5	5	1	0	0	0	0
14	URN5CHAR	DISCUSSION	1	73	23	146	3.26	0:30	5	5	2	0	0	0	0
15	URN5CHAR	HOMEWORK	1	73	73	146	0.	0: 0	1	0	0	0	0	0	0
16	SERVROUT	UNGUID.PRACT	1	73	24	146	3.12	1:30	4	6	2	0	0	0	0
17	TBSHPRIN	PRESENTATION	1	73	24	146	3.04	0:30	4	4	1	0	0	0	0
18	TBSHPRIN	HOMEWORK	1	73	73	146	0.	0: 0	1	0	0	0	0	0	0
19	TBSHPRIN	PRESENTATION	1	73	23	146	3.17	1: 0	6	6	1	0	0	0	0
20	TBSHPRIN	HOMEWORK	1	73	73	146	0.	0: 0	1	0	0	0	0	0	0
21	TBSHURN5	UNGUID.PRACT	1	73	23	146	3.29	1:30	5	6	2	0	0	0	0
22	FLTCHK..	PRESENTATION	1	73	22	146	3.32	0:30	6	6	1	0	0	0	0
23	FLTCHK..	HOMEWORK	1	73	73	146	0.	0: 0	1	0	0	0	0	0	0
24	INSTALL.	PRESENTATION	1	73	22	146	3.32	0:30	6	6	1	0	0	0	0
25	INSTALL.	HOMEWORK	1	73	73	146	0.	0: 0	1	0	0	0	0	0	0
26	REVIEW1.	REVIEW	1	73	22	146	3.32	0:30	6	6	1	0	0	0	0
27	EXAM1...	TEST	1	73	22	146	3.32	0:30	6	6	1	0	0	0	0
28	EXAM1...	TEST	1	73	22	146	3.32	0:30	6	6	1	0	0	0	0
29	CRITQ1..	TEST	1	73	22	146	3.32	0:15	6	6	1	12	12	0	0
30	TESTEQP.	PRESENTATION	3	90	90	110	3.00	1: 7	1	6	6	0	0	0	0
31	TESTEQP.	HOMEWORK	3	90	90	110	0.	0: 0	1	0	0	0	0	0	0
32	TESTEQP.	PRESENTATION	3	90	90	110	3.00	0:45	1	6	6	0	0	0	0
33	TESTEQP.	HOMEWORK	3	90	90	110	0.	0: 0	1	0	0	0	0	0	0
34	URN5CHAR	PRESENTATION	3	90	90	110	3.00	1:29	1	6	6	0	0	0	0
35	URN5CHAR	HOMEWORK	3	90	90	110	0.	0: 0	1	0	0	0	0	0	0
36	URN5CHAR	GUID. PRACT.	3	90	90	110	3.00	1:35	1	6	6	0	0	0	0
37	URN5CHAR	UNGUID.PRACT	3	90	90	110	3.00	4:11	1	6	6	0	0	0	0
38	URN5CHAR	DISCUSSION	3	90	39	110	2.31	0:24	3	3	1	0	0	0	0
39	URN5CHAR	HOMEWORK	3	90	90	110	0.	0: 0	1	0	0	0	0	0	0
40	SERVROUT	UNGUID.PRACT	3	90	26	110	3.46	0:30	5	5	1	0	0	0	0
41	URN5CHAR	GUID. PRACT.	3	90	90	110	3.65	1:35	1	6	6	0	0	0	0

TIME = 768: 0 (HOURS,MINUTES)

----- STUDENTS AND SECTIONS BY LEARNING EVENT NUMBER ----

LE. NO.	OBJECTIVE	EVENT DESCRIPTOR	ELIG. CATE-GORIES	CUMULATIVE STU-DENT ENTRIES	CUMULATIVE SEC-TIONS COMPLTD	CUMULATIVE STU-DENT SKIPS	AVG. NO.OF STDTS	AVERAGE TIME PER STUDENT	MAXIMUM SECTION SIZE ACHIEVED	MAXIMUM NO.OF STDTS.	MAXIMUM NO.OF CONCURRENT SECTIONS	(IF TEST) CUMULATIVE FAILS	(IF TEST) CUMULATIVE RECYCLES	CURRENT STU-DENTS	CURRENT SEC-TION
42	URN5CHAR	UNGUID.PRACT	3	90	90	110	3.71	4:11	1	6	6	0	0	0	0
43	URN5CHAR	DISCUSSION	3	90	39	110	2.31	0:24	3	3	1	0	0	0	0
44	URN5CHAR	HOMEWORK	3	90	90	110	0.	0: 0	1	0	0	0	0	0	0
45	SERVROUT	UNGUID.PRACT	3	90	24	110	3.75	1:30	6	6	1	0	0	0	0
46	TBSHPRIN	PRESENTATION	3	90	85	110	3.74	0:23	1	6	6	0	0	5	5
47	TBSHPRIN	HOMEWORK	3	85	85	110	0.	0: 0	1	0	0	0	0	0	0
48	TBSHPRIN	PRESENTATION	3	85	85	110	3.70	0:45	1	6	6	0	0	0	0
49	TBSHPRIN	HOMEWORK	3	85	85	110	0.	0: 0	1	0	0	0	0	0	0
50	TBSHURN5	UNGUID.PRACT	3	85	23	110	3.70	1:30	6	6	1	0	0	0	0
51	FLTCHK..	PRESENTATION	3	85	85	110	3.70	0:23	1	6	6	0	0	0	0
52	FLTCHK..	HOMEWORK	3	85	85	110	0.	0: 0	1	0	0	0	0	0	0
53	INSTALL.	PRESENTATION	3	85	85	110	3.70	0:23	1	6	6	0	0	0	0
54	INSTALL.	HOMEWORK	3	85	85	110	0.	0: 0	1	0	0	0	0	0	0
55	EXAM1...	TEST	3	85	85	110	3.70	0:30	1	6	6	0	0	0	0
56	EXAM1...	TEST	3	85	24	110	3.62	0:30	6	6	2	0	0	0	0
57	CRITQ1..	TEST	3	85	24	110	3.54	0:15	6	6	1	2	5	0	0
58	TESTEQP.	PRESENTATION	2	22	22	166	1.29	0:45	1	3	3	0	0	0	0
59	TESTEQP.	HOMEWORK	2	22	22	166	0.	0: 0	1	0	0	0	0	0	0
60	URN5CHAR	PRESENTATION	2 4	61	61	127	2.00	1:29	1	5	5	0	0	0	0
61	URN5CHAR	HOMEWORK	2 4	61	61	127	0.	0: 0	1	0	0	0	0	0	0
62	URN5CHAR	GUID. PRACT.	2 4	61	61	127	2.02	1:35	1	5	5	0	0	0	0
63	URN5CHAR	UNGUID.PRACT	2 4	61	61	127	2.26	4:11	1	5	5	0	0	0	0
64	URN5CHAR	DISCUSSION	2 4	61	27	127	2.26	0:24	3	3	1	0	0	0	0
65	URN5CHAR	HOMEWORK	2 4	61	61	127	0.	0: 0	1	0	0	0	0	0	0
66	SERVROUT	UNGUID.PRACT	2 4	61	18	127	3.39	0:30	5	5	1	0	0	0	0
67	URN5CHAR	GUID. PRACT.	2 4	61	61	127	3.52	1:35	1	6	6	0	0	0	0
68	URN5CHAR	UNGUID.PRACT	2 4	61	61	127	3.56	4:11	1	6	6	0	0	0	0
69	URN5CHAR	DISCUSSION	2 4	61	27	127	2.26	0:24	3	3	1	0	0	0	0
70	URN5CHAR	HOMEWORK	2 4	61	61	127	0.	0: 0	1	0	0	0	0	0	0
71	SERVROUT	UNGUID.PRACT	2 4	61	17	127	3.59	1:30	6	6	1	0	0	0	0
72	TBSHPRIN	PRESENTATION	2 4	61	61	127	3.59	0:23	1	6	6	0	0	0	0
73	TBSHPRIN	HOMEWORK	2 4	61	61	127	0.	0: 0	1	0	0	0	0	0	0
74	TBSHPRIN	PRESENTATION	2 4	61	61	127	3.59	0:45	1	6	6	0	0	0	0
75	TBSHPRIN	HOMEWORK	2 4	61	61	127	0.	0: 0	1	0	0	0	0	0	0
76	TBSHURN5	UNGUID.PRACT	2 4	61	16	127	3.57	1:25	6	6	1	0	0	4	1
77	FLTCHK..	PRESENTATION	2 4	57	57	127	3.56	0:23	1	6	6	0	0	0	0
78	FLTCHK..	HOMEWORK	2 4	57	57	127	0.	0: 0	1	0	0	0	0	0	0
79	INSTALL.	PRESENTATION	2 4	57	57	127	3.56	0:23	1	6	6	0	0	0	0
80	INSTALL.	HOMEWORK	2 4	57	57	127	0.	0: 0	1	0	0	0	0	0	0
81	REVIEW1.	REVIEW	2	17	8	166	2.13	0:30	3	3	1	0	0	0	0
82	EXAM1...	TEST	2 4	56	56	127	2.55	0:30	1	4	4	0	0	0	0
83	EXAM1...	TEST	2 4	56	21	127	2.67	0:30	4	4	1	0	0	0	0
84	CRITQ1..	TEST	2 4	56	22	127	2.55	0:15	4	4	1	8	0	0	0

TIME = 768: 0

----- STUDENT QUEUES BY LEARNING EVENT -----

	QUEUES FOR RESOURCES							QUEUES FOR OTHER STUDENTS						
LE	AVERAGE NO.OF STUDENTS	MAX NO.OF STUDENTS	AVERAGE TIME IN QUEUE	$AVERAGE TIME IN QUEUE	CUMU- LATIVE ENTRIES	ZERO TIME ENTRIES	CURRENT STUDENTS	AVERAGE NO.OF STUDENTS	MAX NO.OF STUDENTS	AVERAGE TIME IN QUEUE	$AVERAGE TIME IN QUEUE	CUMU- LATIVE ENTRIES	ZERO TIME ENTRIES	CURRENT STUDENTS
1	0	0	0: 0	0: 0	0	0	0	1	1	4:43	17:40	45	33	1
2	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	73	73	0
3	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
4	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	73	73	0
5	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
6	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	73	73	0
7	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
8	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
9	3	4	0:47	0:47	6	0	0	0	0	0: 0	0: 0	46	46	0
10	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	73	73	0
11	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
12	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
13	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
14	2	4	0:26	0:26	10	0	0	1	1	0:47	17:52	46	44	0
15	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	73	73	0
16	3	4	0:52	0:52	13	0	0	1	1	3:45	35:60	48	43	0
17	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	48	48	0
18	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	73	73	0
19	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	46	46	0
20	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	73	73	0
21	1	2	0:10	0:10	4	0	0	0	0	0: 0	0: 0	46	46	0
22	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
23	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	73	73	0
24	2	2	0:27	0:27	4	0	0	0	0	0: 0	0: 0	44	44	0
25	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	73	73	0
26	2	2	0:24	0:24	4	0	0	0	0	0: 0	0: 0	44	44	0
27	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
28	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
29	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	44	44	0
30	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
31	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
32	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
33	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
34	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
35	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
36	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
37	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
38	3	4	0:16	0:16	70	0	0	1	1	1:15	16:12	78	72	0
39	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
40	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	52	52	0
41	2	4	0:18	0:18	8	0	0	0	0	0: 0	0: 0	90	90	0

TIME = 768: 0

----- STUDENT QUEUES BY LEARNING EVENT -----

	QUEUES FOR RESOURCES							QUEUES	FOR OTHER STUDENTS					
42	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
43	3	4	0:16	0:16	72	0	0	0	0	0: 0	0: 0	78	78	0
44	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	90	90	0
45	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	48	48	0
46	0	1	0: 1	0: 1	1	0	0	0	0	0: 0	0: 0	90	90	0
47	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	85	85	0
48	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	85	85	0
49	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	85	85	0
50	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	46	46	0
51	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	85	85	0
52	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	85	85	0
53	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	85	85	0
54	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	85	85	0
55	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	85	85	0
56	1	4	0:16	0:16	4	0	0	0	0	0: 0	0: 0	48	48	0
57	2	4	0:15	0:15	6	0	0	0	0	0: 0	0: 0	48	48	0
58	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	22	22	0
59	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	22	22	0
60	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
61	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
62	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
63	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
64	3	4	0:45	0:45	50	0	0	1	1	5: 2	18: 9	54	39	0
65	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
66	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	36	36	0
67	1	4	0:18	0:18	4	0	0	0	0	0: 0	0: 0	61	61	0
68	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
69	2	4	0:13	0:13	50	0	0	0	0	0: 0	0: 0	54	54	0
70	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
71	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	34	34	0
72	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
73	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
74	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
75	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	61	61	0
76	0	0	0: 0	0: 0	0	0	0	1	1	1:49	31: 1	34	32	0
77	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	57	57	0
78	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	57	57	0
79	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	57	57	0
80	0	0	0: 0	0: 0	0	0	0	0	0	0: 0	0: 0	57	57	0
81	2	2	0:30	0:30	12	0	0	1	1	17:22	59: 3	17	12	1
82	2	2	0:25	0:25	6	0	0	0	0	0: 0	0: 0	56	56	0
83	0	0	0: 0	0: 0	0	0	0	1	1	1:26	30:15	42	40	0
84	2	2	0:16	0:16	16	0	0	1	1	0:44	16: 1	44	42	0

$AVERAGE TIME IN QUEUE = AVERAGE TIME IN QUEUE - ZERO TIME ENTRIES

TIME = 768: 0

----- RESOURCE UTILIZATION BY LEARNING EVENT -----

LE NO.	RESOURCE: NO.	NAME	CAPACITY (IN STUDENTS)	CURRENT NO. OF UNITS IN USE	RESERVED	REQUESTED	MAX IN CON-CURRENT USE FOR THIS LE	CUMULATIVE USE HOURS	CUMULATIVE STUDENT USE HOURS
1	5	INSTRCTR	6	0.	0.	0.	1.000	33: 0	109:30
	10	ROOM1...	6	0.	0.	0.	1.000	33: 0	109:30
	14	I.SV....	6	0.	0.	0.	1.000	33: 0	109:30
2									
3	5	INSTRCTR	6	0.	0.	0.	1.000	22: 0	73: 0
	10	ROOM1...	6	0.	0.	0.	1.000	22: 0	73: 0
	14	I.SV....	6	0.	0.	0.	1.000	22: 0	73: 0
4									
5	5	INSTRCTR	6	0.	0.	0.	1.000	44: 0	146: 0
	10	ROOM1...	6	0.	0.	0.	1.000	44: 0	146: 0
	14	I.SV....	6	0.	0.	0.	1.000	44: 0	146: 0
6									
7	5	INSTRCTR	4	0.	0.	0.	2.000	43:60	133:50
	10	ROOM1...	6	0.	0.	0.	1.000	40:20	133:50
8	5	INSTRCTR	6	0.	0.	0.	1.000	80:40	267:40
	10	ROOM1...	6	0.	0.	0.	1.000	80:40	267:40
9	5	INSTRCTR	6	0.	0.	0.	2.000	11:30	36:30
	10	ROOM1...	6	0.	0.	0.	2.000	11:30	36:30
	14	I.SV....	6	0.	0.	0.	2.000	11:30	36:30
10									
11	1	ANURN5..	2	0.	0.	0.	3.000	21: 0	36:30
	2	TSNR1...	2	0.	0.	0.	3.000	21: 0	36:30
	3	TSNR2...	2	0.	0.	0.	3.000	21: 0	36:30
	4	SIGGEN..	2	0.	0.	0.	3.000	21: 0	36:30
	9	LAB.MON	6	0.	0.	0.	.833	6: 5	36:30
	13	LAB.....	20	0.	0.	0.	.250	1:49	36:30
	16	L.SV....	1	0.	0.	0.	5.000	36:30	36:30
12	5	INSTRCTR	4	0.	0.	0.	2.000	43:60	133:50
	10	ROOM1...	6	0.	0.	0.	1.000	40:20	133:50
13	5	INSTRCTR	6	0.	0.	0.	1.000	80:40	267:39
	10	ROOM1...	6	0.	0.	0.	.833	44:37	267:39
14	5	INSTRCTR	6	0.	0.	0.	2.000	11:30	36:30
	10	ROOM1...	6	0.	0.	0.	2.000	11:30	36:30
	14	I.SV....	6	0.	0.	0.	2.000	11:30	36:30

TIME = 768: 0

----- RESOURCE UTILIZATION BY LEARNING EVENT -----

15								
16	1 ANURN5..	2	0.	0.	0.	3.000	58:30	109:30
	2 TSNR1...	2	0.	0.	0.	3.000	58:30	109:30
	3 TSNR2...	2	0.	0.	0.	3.000	58:30	109:30
	4 SIGGEN..	2	0.	0.	0.	3.000	58:30	109:30
	9 LAB.MON	6	0.	0.	0.	1.000	18:15	109:30
	13 LAB.....	20	0.	0.	0.	.300	5:28	109:30
	16 L.SV....	1	0.	0.	0.	6.000	109:30	109:30
17	5 INSTRCTR	6	0.	0.	0.	1.000	12: 0	36:30
	10 ROOM1...	6	0.	0.	0.	1.000	12: 0	36:30
	14 I.SV....	6	0.	0.	0.	1.000	12: 0	36:30
18								
19	5 INSTRCTR	6	0.	0.	0.	1.000	23: 0	73: 0
	10 ROOM1...	6	0.	0.	0.	1.000	23: 0	73: 0
	14 I.SV....	6	0.	0.	0.	1.000	23: 0	73: 0
20								
21	1 ANURN5..	2	0.	0.	0.	3.000	58:30	109:30
	2 TSNR1...	2	0.	0.	0.	3.000	58:30	109:30
	3 TSNR2...	2	0.	0.	0.	3.000	58:30	109:30
	4 SIGGEN..	2	0.	0.	0.	3.000	58:30	109:30
	9 LAB.MON	6	0.	0.	0.	1.000	18:15	109:30
	13 LAB.....	20	0.	0.	0.	.300	5:28	109:30
	16 L.SV....	1	0.	0.	0.	6.000	109:30	109:30
22	5 INSTRCTR	6	0.	0.	0.	1.000	11: 0	36:30
	10 ROOM1...	6	0.	0.	0.	1.000	11: 0	36:30
	14 I.SV....	6	0.	0.	0.	1.000	11: 0	36:30
23								
24	5 INSTRCTR	6	0.	0.	0.	1.000	11: 0	36:30
	10 ROOM1...	6	0.	0.	0.	1.000	11: 0	36:30
	14 I.SV....	6	0.	0.	0.	1.000	11: 0	36:30
25								
26	5 INSTRCTR	6	0.	0.	0.	1.000	11: 0	36:30
	10 ROOM1...	6	0.	0.	0.	1.000	11: 0	36:30
	14 I.SV....	6	0.	0.	0.	1.000	11: 0	36:30
27	5 INSTRCTR	16	0.	0.	0.	.375	2:17	36:30
	10 ROOM1...	6	0.	0.	0.	1.000	6: 5	36:30
	16 L.SV....	1	0.	0.	0.	6.000	36:30	36:30
28	1 ANURN5..	2	0.	0.	0.	3.000	19:30	36:30
	2 TSNR1...	2	0.	0.	0.	3.000	19:30	36:30
	3 TSNR2...	2	0.	0.	0.	3.000	19:30	36:30
	4 SIGGEN..	2	0.	0.	0.	3.000	19:30	36:30
	6 EVALUATR	4	0.	0.	0.	2.000	12: 0	36:30
	13 LAB.....	20	0.	0.	0.	.300	1:49	36:30
	16 L.SV....	1	0.	0.	0.	6.000	36:30	36:30

TIME = 768: 0

----- RESOURCE UTILIZATION BY LEARNING EVENT -----

29	5	INSTRCTR	6	0.	0.	0.	1.000	5:30	18:15
	6	EVALUATR	6	0.	0.	0.	1.000	5:30	18:15
	10	ROOM1...	6	0.	0.	0.	1.000	5:30	18:15
30	7	RM2.MON	12	0.	0.	0.	.500	8:22	100:29
	11	ROOM2...	12	0.	0.	0.	.500	8:22	100:29
	17	P.SV....	1	0.	0.	0.	6.000	100:29	100:29
31									
32	7	RM2.MON	12	0.	0.	0.	.500	5:37	67:30
	11	ROOM2...	12	0.	0.	0.	.500	5:37	67:30
	17	P.SV....	1	0.	0.	0.	6.000	67:30	67:30
33									
34	7	RM2.MON	12	0.	0.	0.	.500	11: 7	133:29
	11	ROOM2...	12	0.	0.	0.	.500	11: 7	133:29
	17	P.SV....	1	0.	0.	0.	6.000	133:29	133:29
35									
36	7	RM2.MON	12	0.	0.	0.	.500	11:52	142:30
	11	ROOM2...	12	0.	0.	0.	.500	11:52	142:30
	16	L.SV....	1	0.	0.	0.	6.000	142:30	142:30
37	7	RM2.MON	12	0.	0.	0.	.500	31:22	376:29
	11	ROOM2...	12	0.	0.	0.	.500	31:22	376:29
38	5	INSTRCTR	6	0.	0.	0.	1.000	15:36	35:60
	11	ROOM2...	12	0.	0.	-.000	1.000	15:36	35:60
	14	I.SV....	6	0.	0.	0.	1.000	15:36	35:60
39									
40	1	ANURN5..	2	0.	0.	0.	3.000	25:30	45: 0
	2	TSNR1...	2	0.	0.	0.	3.000	25:30	45: 0
	3	TSNR2...	2	0.	0.	0.	3.000	25:30	45: 0
	4	SIGGEN..	2	0.	0.	0.	3.000	25:30	45: 0
	9	LAB.MON	6	0.	0.	0.	.833	7:30	45: 0
	13	LAB.....	20	0.	0.	0.	.250	2:15	45: 0
	16	L.SV....	1	0.	0.	0.	5.000	45: 0	45: 0
41	7	RM2.MON	12	0.	0.	0.	.500	11:52	142:30
	11	ROOM2...	12	0.	0.	0.	.500	11:52	142:30
	16	L.SV....	1	0.	0.	0.	6.000	142:30	142:30
42	7	RM2.MON	12	0.	0.	0.	.500	31:22	376:29
	11	ROOM2...	12	0.	0.	0.	.500	31:22	376:29
43	5	INSTRCTR	6	0.	0.	0.	1.000	15:36	35:60
	11	ROOM2...	12	0.	0.	-.000	1.000	15:36	35:60
	14	I.SV....	6	0.	0.	0.	1.000	15:36	35:60
44									
45	1	ANURN5..	2	0.	0.	0.	3.000	76:30	135: 0
	2	TSNR1...	2	0.	0.	0.	3.000	76:30	135: 0

TIME = 768: 0

----- RESOURCE UTILIZATION BY LEARNING EVENT -----

	3 TSNR2...	2	0.	0.	0.	3.000	76:30	135: 0
	4 SIGGEN..	2	0.	0.	0.	3.000	76:30	135: 0
	9 LAB.MON	6	0.	0.	0.	1.000	22:30	135: 0
	13 LAB.....	20	0.	0.	0.	.300	6:45	135: 0
	16 L.SV....	1	0.	0.	0.	6.000	135: 0	135: 0
46	7 RM2.MON	12	.417	0.	0.	.500	2:51	34: 9
	11 ROOM2...	12	.417	0.	0.	.500	2:51	34: 9
	17 P.SV....	1	5.000	0.	0.	6.000	34: 9	34: 9
47								
48	7 RM2.MON	12	0.	0.	0.	.500	5:19	63:45
	11 ROOM2...	12	0.	0.	0.	.500	5:19	63:45
	17 P.SV....	1	0.	0.	0.	6.000	63:45	63:45
49								
50	1 ANURN5..	2	0.	0.	0.	3.000	72: 0	127:30
	2 TSNR1...	2	0.	0.	0.	3.000	72: 0	127:30
	3 TSNR2...	2	0.	0.	0.	3.000	72: 0	127:30
	4 SIGGEN..	2	0.	0.	0.	3.000	72: 0	127:30
	9 LAB.MON	6	0.	0.	0.	1.000	21:15	127:30
	13 LAB.....	20	0.	0.	0.	.300	6:22	127:30
	16 L.SV....	1	0.	0.	0.	6.000	127:30	127:30
51	7 RM2.MON	12	0.	0.	0.	.500	2:43	32:35
	11 ROOM2...	12	0.	0.	0.	.500	2:43	32:35
	17 P.SV....	1	0.	0.	0.	6.000	32:35	32:35
52								
53	7 RM2.MON	12	0.	0.	0.	.500	2:43	32:35
	11 ROOM2...	12	0.	0.	0.	.500	2:43	32:35
	17 P.SV....	1	0.	0.	0.	6.000	32:35	32:35
54								
55	7 RM2.MON	12	0.	0.	0.	.500	3:32	42:30
	11 ROOM2...	12	0.	0.	0.	.500	3:32	42:30
	16 L.SV....	1	0.	0.	0.	6.000	42:30	42:30
56	1 ANURN5..	2	0.	0.	0.	3.000	24: 0	42:30
	2 TSNR1...	2	0.	0.	0.	3.000	24: 0	42:30
	3 TSNR2...	2	0.	0.	0.	3.000	24: 0	42:30
	4 SIGGEN..	2	0.	0.	0.	3.000	24: 0	42:30
	6 EVALUATR	4	0.	0.	0.	2.000	15: 0	42:30
	13 LAB.....	20	0.	0.	0.	.300	2: 7	42:30
	16 L.SV....	1	0.	0.	0.	6.000	42:30	42:30
57	5 INSTRCTR	6	0.	0.	0.	1.000	6: 0	21:15
	6 EVALUATR	6	0.	0.	0.	1.000	6: 0	21:15
	11 ROOM2...	12	0.	0.	0.	1.000	6: 0	21:15
58	8 RM3.MON	12	0.	0.	0.	.250	1:22	16:30
	12 ROOM3...	12	0.	0.	0.	.250	1:22	16:30
	17 P.SV....	1	0.	0.	0.	3.000	16:30	16:30

TIME = 768: 0

----- RESOURCE UTILIZATION BY LEARNING EVENT -----

59								
60	8 RM3.MON	12	0.	0.	0.	.417	7:32	90:29
	12 ROOM3...	12	0.	0.	0.	.417	7:32	90:29
	17 P.SV....	1	0.	0.	0.	5.000	90:29	90:29
61								
62	8 RM3.MON	12	0.	0.	0.	.417	8: 3	96:35
	12 ROOM3...	12	0.	0.	0.	.417	8: 3	96:35
	16 L.SV....	1	0.	0.	0.	5.000	96:35	96:35
63	8 RM3.MON	12	0.	0.	0.	.417	21:16	255:10
	12 ROOM3...	12	0.	0.	0.	.417	21:16	255:10
64	5 INSTRCTR	6	0.	0.	0.	1.000	10:48	24:24
	12 ROOM3...	12	0.	0.	-.000	1.000	10:48	24:24
	14 I.SV....	6	0.	0.	0.	1.000	10:48	24:24
65								
66	1 ANURN5..	2	0.	0.	0.	3.000	17: 0	30:30
	2 TSNR1...	2	0.	0.	0.	3.000	17: 0	30:30
	3 TSNR2...	2	0.	0.	0.	3.000	17: 0	30:30
	4 SIGGEN..	2	0.	0.	0.	3.000	17: 0	30:30
	9 LAB.MON	6	0.	0.	0.	.833	5: 5	30:30
	13 LAB.....	20	0.	0.	0.	.250	1:31	30:30
	16 L.SV....	1	0.	0.	0.	5.000	30:30	30:30
67	8 RM3.MON	12	0.	0.	0.	.500	8: 3	96:35
	12 ROOM3...	12	0.	0.	0.	.500	8: 3	96:35
	16 L.SV....	1	0.	0.	0.	6.000	96:35	96:35
68	8 RM3.MON	12	0.	0.	0.	.500	21:16	255:10
	12 ROOM3...	12	0.	0.	0.	.500	21:16	255:10
69	5 INSTRCTR	6	0.	0.	0.	1.000	10:48	24:24
	12 ROOM3...	12	0.	0.	-.000	1.000	10:48	24:24
	14 I.SV....	6	0.	0.	0.	1.000	10:48	24:24
70								
71	1 ANURN5..	2	0.	0.	0.	3.000	51: 0	91:30
	2 TSNR1...	2	0.	0.	0.	3.000	51: 0	91:30
	3 TSNR2...	2	0.	0.	0.	3.000	51: 0	91:30
	4 SIGGEN..	2	0.	0.	0.	3.000	51: 0	91:30
	9 LAB.MON	6	0.	0.	0.	1.000	15:15	91:30
	13 LAB.....	20	0.	0.	0.	.300	4:34	91:30
	16 L.SV....	1	0.	0.	0.	6.000	91:30	91:30
72	8 RM3.MON	12	0.	0.	0.	.500	1:57	23:23
	12 ROOM3...	12	0.	0.	0.	.500	1:57	23:23
	17 P.SV....	1	0.	0.	0.	6.000	23:23	23:23
73								
74	8 PM3.MON	12	0.	0.	0.	.500	3:49	45:45

TIME = 768: 0

----- RESOURCE UTILIZATION BY LEARNING EVENT -----

	12	ROOM3...	12	0.	0.	0.	.500	3:49	45:45
	17	P.SV....	1	0.	0.	0.	6.000	45:45	45:45
75									
76	1	ANURN5..	2	2.000	0.	0.	3.000	47: 6	86:42
	2	TSNR1...	2	2.000	0.	0.	3.000	47: 6	86:42
	3	TSNR2...	2	2.000	0.	0.	3.000	47: 6	86:42
	4	SIGGEN..	2	2.000	0.	0.	3.000	47: 6	86:42
	9	LAB.MON	6	.667	0.	0.	1.000	14:27	86:42
	13	LAB.....	20	.200	0.	0.	.300	4:20	86:42
	16	L.SV....	1	4.000	0.	0.	6.000	86:42	86:42
77	8	RM3.MON	12	0.	0.	0.	.500	1:49	21:51
	12	ROOM3...	12	0.	0.	0.	.500	1:49	21:51
	17	P.SV....	1	0.	0.	0.	6.000	21:51	21:51
78									
79	8	RM3.MON	12	0.	0.	0.	.500	1:49	21:51
	12	ROOM3...	12	0.	0.	0.	.500	1:49	21:51
	17	P.SV....	1	0.	0.	0.	6.000	21:51	21:51
80									
81	5	INSTRCTR	6	0.	0.	0.	1.000	4: 0	8:30
	12	ROOM3...	12	0.	0.	0.	1.000	4: 0	8:30
	14	I.SV....	6	0.	0.	0.	1.000	4: 0	8:30
82	8	RM3.MON	12	0.	0.	0.	.333	2:20	28: 0
	12	ROOM3...	12	0.	0.	0.	.333	2:20	28: 0
	16	L.SV....	1	0.	0.	0.	4.000	28: 0	28: 0
83	1	ANURN5..	2	0.	0.	0.	2.000	15:30	28: 0
	2	TSNR1...	2	0.	0.	0.	2.000	15:30	28: 0
	3	TSNR2...	2	0.	0.	0.	2.000	15:30	28: 0
	4	SIGGEN..	2	0.	0.	0.	2.000	15:30	28: 0
	6	EVALUATR	4	0.	0.	0.	1.000	10:30	28: 0
	13	LAB.....	20	0.	0.	0.	.200	1:24	28: 0
	16	L.SV....	1	0.	0.	0.	4.000	28: 0	28: 0
84	5	INSTRCTR	6	0.	0.	0.	1.000	5:30	14: 0
	6	EVALUATR	6	0.	0.	0.	1.000	5:30	14: 0
	12	ROOM3...	12	0.	0.	0.	1.000	5:30	14: 0

TIME = 768: 0

RESOURCE UTILIZATION BY RESOURCE TYPE

RESOURCE NO.	NAME	QTY.LTD? YES	QTY.LTD? NO	TOTAL NO. OF UNITS CURRENTLY IN SYSTEM	IN USE	RESERVED	REQUESTED	MAXIMUM NO.OF UNITS CONCURRENTLY IN USE	TOTAL ACTUAL USE HOURS	TOTAL UNIT-HOURS	AVERAGE PER CENT UNIT-HOURS FULLY IDLE
1	ANURN5..	X		4.00	2.00	0.	0.	4.000	481:56	3072: 0	84.31
2	TSNR1...	X		4.00	2.00	0.	0.	4.000	481:56	3072: 0	84.31
3	TSNR2...	X		4.00	2.00	0.	0.	4.000	481:56	3072: 0	84.31
4	SIGGEN..	X		4.00	2.00	0.	0.	4.000	481:56	3072: 0	84.31
5	INSTRCTR	X		2.00	0.	0.	0.	2.000	515:24	1536: 0	65.42
6	EVALUATR	X		2.00	0.	0.	0.	2.000	54:30	1536: 0	96.45
7	PM2.MON	X		1.00	.42	0.	0.	.500	128:45	768: 0	40.11
8	RM3.MON	X		1.00	0.	0.	0.	.500	79:16	768: 0	56.37
9	LAB.MON	X		2.00	.67	0.	0.	1.333	127:33	1536: 0	43.63
10	ROOM1...	X		2.00	-.00	0.	0.	2.000	407:29	1536: 0	51.37
11	ROOM2...	X		1.00	.42	0.	-.00	1.000	165:57	768: 0	35.27
12	ROOM3...	X		1.00	0.	-.00	-.00	1.000	110:22	768: 0	52.32
13	LAB.....	X		1.00	.20	0.	0.	.400	43:33	768: 0	73.21
14	I.SV....	X		2.00	0.	0.	0.	2.000	246:47	1536: 0	83.93
15	L.ASV...		X	0.	0.	0.	0.	0.	0: 0	0: 0	0.
16	L.SV....	X		34.00	4.00	0.	0.	10.000	1455: 8	26112: 0	94.42
17	P.SV....	X		8.00	5.00	0.	0.	8.000	684:21	6144: 0	88.86

TIME = 768: 0

SECTIONS QUEUED BY RESOURCE TYPE

RESOURCE TYPE	AVERAGE NO.OF SECTIONS	MAXIMUM NO.OF SECTIONS	AVERAGE TIME IN QUEUE	$AVERAGE TIME IN QUEUE	CUMU- LATIVE __SECTIONS	ZERO TIME SECTIONS_	CURRENT SECTIONS QUEUED
1	1	1	0:38	0:38	6	0	0
2	1	1	0:38	0:38	6	0	0
3	1	1	0:38	0:38	6	0	0
4	1	1	0:38	0:38	6	0	0
5	1	3	0:33	0:33	59	0	0
6	1	2	0:14	0:14	5	0	0
7	0	0	0: 0	0: 0	0	0	0
8	0	0	0: 0	0: 0	0	0	0
9	0	0	0: 0	0: 0	0	0	0
10	1	1	0:31	0:31	4	0	0
11	1	4	0:15	0:15	79	0	0
12	1	4	0:24	0:24	71	0	0
13	0	0	0: 0	0: 0	0	0	0
14	1	2	0:28	0:28	22	0	0
15	0	0	0: 0	0: 0	0	0	0
16	0	0	0: 0	0: 0	0	0	0
17	0	1	0: 1	0: 1	1	0	0

$AVERAGE TIME IN QUEUE = AVERAGE TIME IN QUEUE - ZERO TIME SECTIONS